THE PRACTICAL MAGAZINE WITH THE PROFESSIONAL APPROACH

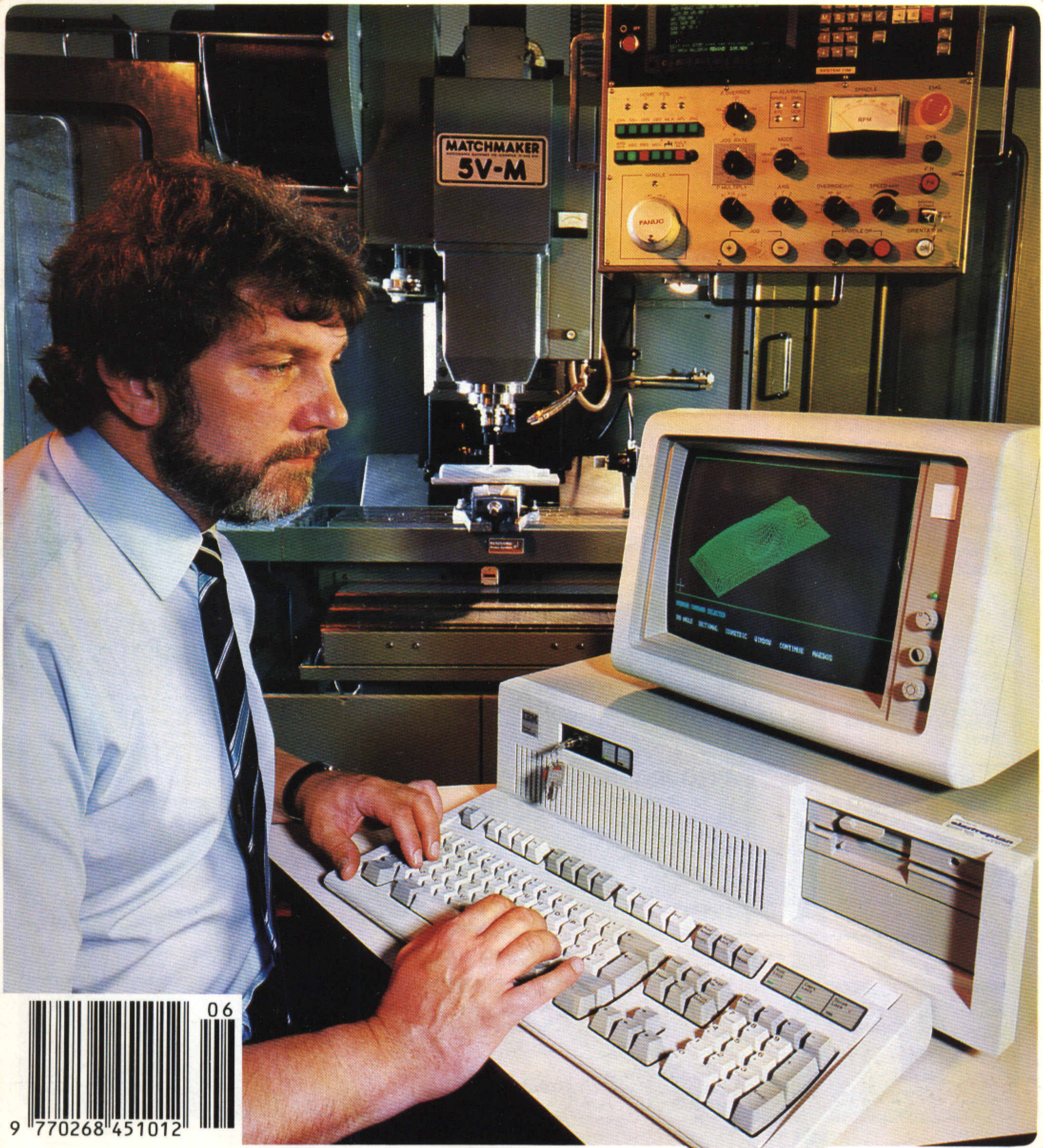
# Elektor Electronics

2 ASSEMBLER 24 PLOTTER
4 CASE 29 ERRORS
11 DISC DRIVE 30
44 POWER SUPPLY 49 EPROM PROG.
55 71

June 1988

**Philips-Sony digital audio interface**
**HF operation of fluorescent tubes**
**Electrostatic paper holder**
**I/O card for IBM PCs**
**Paintbox**

UK £1·50 IR £2·20 (incl. VAT)

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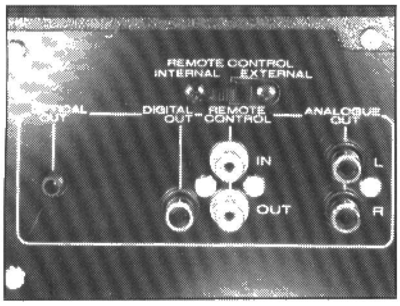
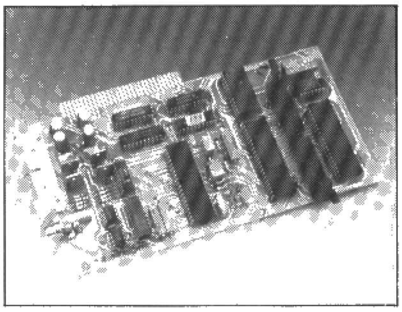
# CONTENTS

June 1988
Volume 14
Number 157

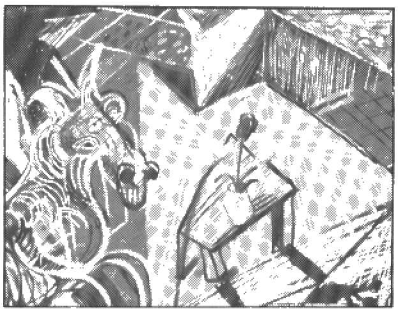



Philips-Sony Digital Audio Interface
p. 14





I/O Extension card for IBM PCs and compatibles
p. 30



Paintbox: The high tech approach to artistic creativity
p. 42



## In next month's issue:

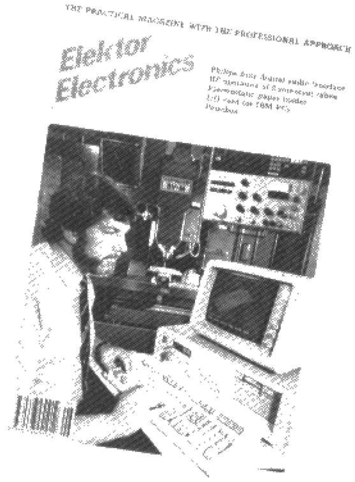
Theme of the month is 'Amateur Radio & Television' and a number of articles are dedicated to that popular subject.

- Chrominance locked clock generator
- Microprocessor-controlled radio synthesizer
- The Jaguar scanning receiver — a review
- GaAs FET converter for 23 cm ATV
- Fast NiCd charger*
- RTTY for radio amateurs
- 60-page supplement with a variety of small design projects

* Our apologies for not including this (and the '64 K RAM for MSX') in the June issue as announced: this was unfortunately due to lack of space.

***Front cover***

A sense of touch is the key to Maetrace, a British system that produces dies and moulds at a fraction of the cost of conventional methods. The sensor probe examines the workpiece to be copied, the information is passed to an on-line computer, and the data is displayed on a VDU. Once a digitalized replica is on the screen, it can be enlarged, reduced or manipulated to meet specific requirements. The Maetrace generated program will do the rest. The accuracy of the equipment means that very little hand finishing is required.



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# ELECTRONICS AND 1992

Following the USSR's good example of *perestroika*, the European Economic Community has decided that it, too, must restructure and become a really integrated market by 1992–more than 30 years after its birth. This time it appears to be not just a hare-brained scheme of some politicians, but a serious endeavour.

It seems that the penny has finally dropped in Brussels that if the countries within the EEC do not act as one, they will be submerged by the products emanating not just from the USA and Japan, but also from the newly developing countries of the Third World. The twelve countries in the EEC, if integrated (commercially, that is), would constitute a single market of 320 million consumers, far more than any of the other trading region in the western world.

To achieve this momentous integration, the EEC Commission proposes by 1992 to abolish all frontier checks (within the EEC), establish common technical standards, and enact community-wide financial services.

The first and last of these three proposals are undoubtedly (or should be) a boon to British industry. Already, the British Electronics Industry exports more than half its products, much of it to fellow members in the Common Market. It must be realized, of course, that the proposed restructuring of the EEC's economic system is a two-edged sword, since our trading partners will just as eagerly want to push their products into Britain (strong pound; healthy consumer market; and so on). From 1992 on, there will be an end to the comfortable and safe home markets.

It is the proposal to achieve common technical standards that Britain must act on now, and the signs are that we are not. The absence of common technical standards in the EEC is costing the member states thousands of millions of pounds. Although nobody will officially admit it, existing national technical standards are, in effect, disguised trade barriers. That is why, over the next few years, a number of battles royal will ensue over whose standards will be adopted.

The two countries with the strongest standards institutions are Federal Germany and Britain. In Germany, this is the Technischer Überwachungs-Verein (TÜV), or Technical Testing Association, while in Britain it is the British Standards Institution (BSI).

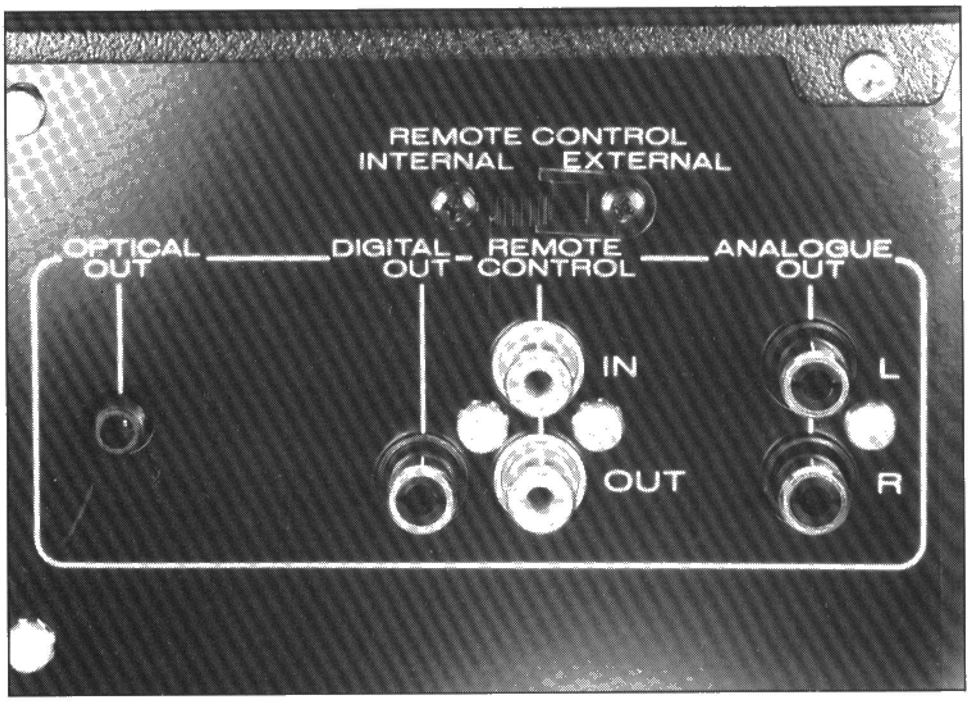
The BSI has been in existence for over 90 years and has over 10,000 standards in its catalogue. It also has excellent working committees to represent all branches of engineering and technology. The Germans, however, are convinced that their standards are the best in the world.

Already, scores of French, German, and other, industrialists have volunteered to serve on the committees that will pound out the new pan-EEC standards over the next few years. As yet, there appears to be a regrettable dearth of British applications. It almost seems as if large sections of our industry are not aware of what is at stake. The greater awareness of our trading partners is, no doubt, due to the greater publicity given to *quatre-vingts douze* on French, German, and Italian television. It should, however, be realized that in Britain, the DTI, too, has set up a special department for providing information to British industry and other organizations on how to prepare for 1992.

We do not believe, as some do, that the whole of British industry lags its trading partners in the EEC by about a year in its preparations for 1992. No doubt, most of our progressive companies are just as advanced in their preparations as their rivals in the EEC. None the less, there are disturbing signs that other British firms have not even begun to realize that something is going on.

# PHILIPS–SONY DIGITAL AUDIO INTERFACE

**As digital techniques find application in more and more branches of electronic engineering, the time cannot be far when audio equipment is also interconnected by digital interfaces. One such interface has been in use for a number of years already: at the output of CD players. This article describes the Philips–Sony design of such an interface.**




In broadcasting and recording studios, the era of digital recording began in the late 1970s. Right from the start, it was realized that in order to transfer digital audio data between the many pieces of equipment, it would be imperative to specify standards for the required interfaces. With the support and participation of the European Broadcasting Union—EBU—and the Audio Engineering Society—AES—a serial interface with high transfer speed was developed, which, under the name AES–EBU Interface has found extensive application in audio studios.

With the advent of the CD player, a similar standard interface was required and subsequently developed as a 'consumer version' of the AES–EBU standard. This version has become known as the 'Philips–Sony–Format', and has been proposed as the basis of an IEC Specification. From day one, this standard has been incorporated in all CD players with digital output.

The most notable external difference between the AES–EBU Interface and the Philips–Sony–Format is the use of a normal audio socket in the latter instead of the symmetrical outputs that are, of course, obligatory in a professional studio. Other differences are that the studio interface has an output impedance of 110 ohms, and an output level of 3–10 $V_{pp}$. Otherwise, the signals and transfer arrangement are similar.

## Specification

The signal at the digital output of a CD player contains no d.c. component, is nearly sinusoidal, and has an amplitude of about 500 $mV_{pp}$ and a frequency of almost 3 kHz. This frequency depends on the sample frequency. Two 32-bit words (one for each stereo channel) are transferred per sample, which, at the CD's sampling rate of 44.1 kHz, gives a transfer rate of 2.8224 Mbit/s. The transfer rate for DAT (sampling rate=48 kHz) is 3.072 Mbit/s, and that for digital broadcast receivers (sampling rate=32 kHz) is 2.048 Mbit/s. The Philips–Sony–Format may be used at all three sampling rates.

All impedances (input, output, and line) have been standardized at 75 ohms, so that coaxial cable may be used for long signal paths. This is particularly useful, since the minimum level for the digital input has been specified at 200 mV. When cables more than 10 metres long are used, it is imperative that all impedances are kept within specification to prevent problems arising during the critical decoding processes.

With optical data transfer via fibre optic cables, the impedances do not present such a problem, because the electrical connection between output and optical transmitter can be kept short. Fibre optic cable, on the other hand, offers greater attenuation. Furthermore, at transfer frequencies above about 1 MHz, it introduces phase shifts because of differences in path lengths.

These problems make careful signal preparation at the receiver side imperative.

## Coding and synchronization

For the transfer of digital data, the so-called Biphase Mark Code is used. This means that for a logic 1 there are two polarity changes (zero crossings) of the signal, and for a logic 0 one polarity change, as shown in Fig. 1. The clock (upper trace) is double the bit rate. Each data bit to be transferred is represented by two sequential logic states, i.e., two bits, which together are treated as one cell. A cell corresponds to the timeslot for one data bit.

The logic state at the onset of a data bit is always the opposite of the state at the end of the preceding data bit. The logic state at the end of a data bit is the same as that at the onset if the bit corresponds

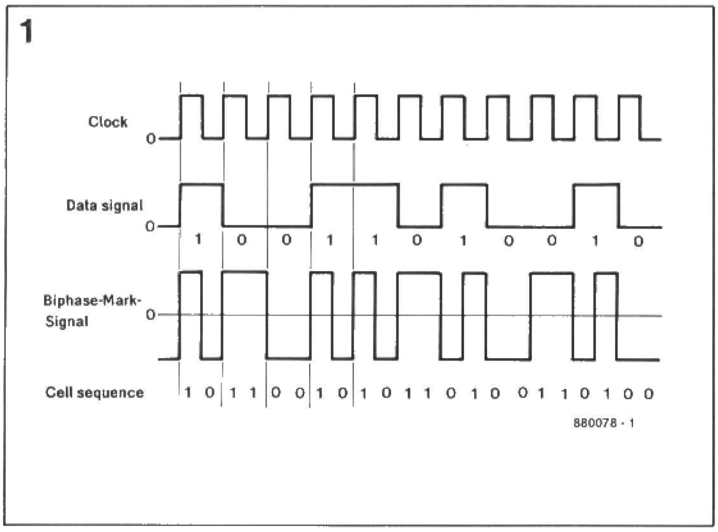



Fig. 1. Coding of the digital audio signal in the Biphase Mark Code. The polarity of the output signal changes after each bit. A logic 1 is identified by a double change of polarity.

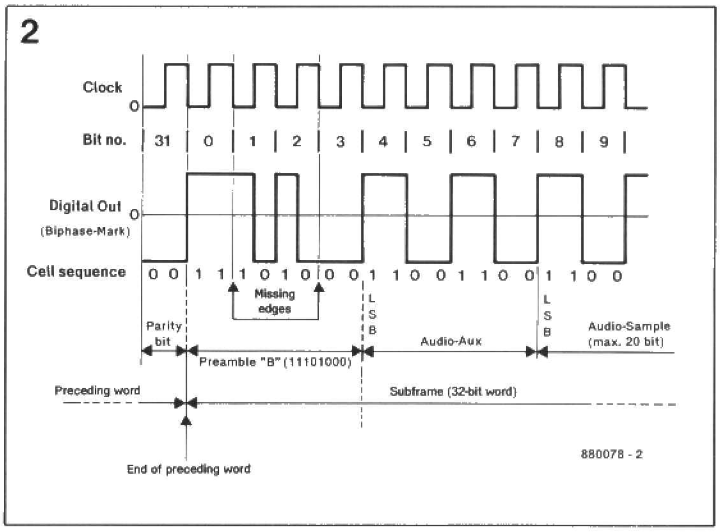



Fig. 2. The first section of a 32-bit word, the subframe, is 4 bits (0 to 3) long. It represents a sync sample, called Preamble, which also marks the onset of a block and channel status.

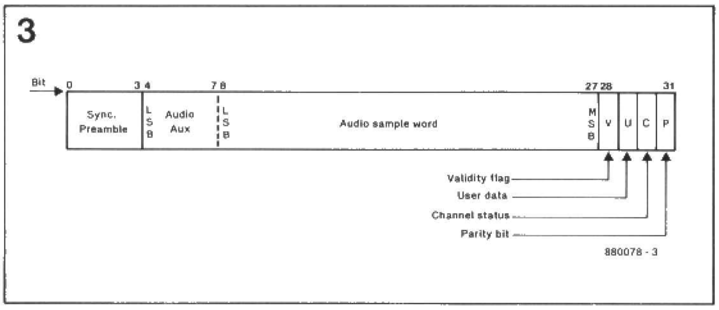



Fig. 3. Data format of a subframe. For audio data, 24 bits are available, of which in a CD sample only 16 are used.

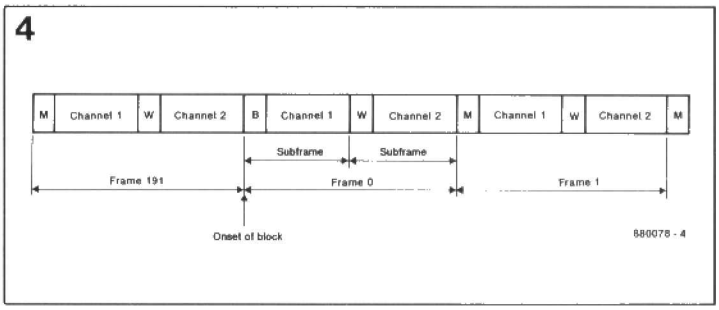



Fig. 4. A block always consists of 192 frames. A frame contains a subframe for each channel: in stereo operation, therefore, two.

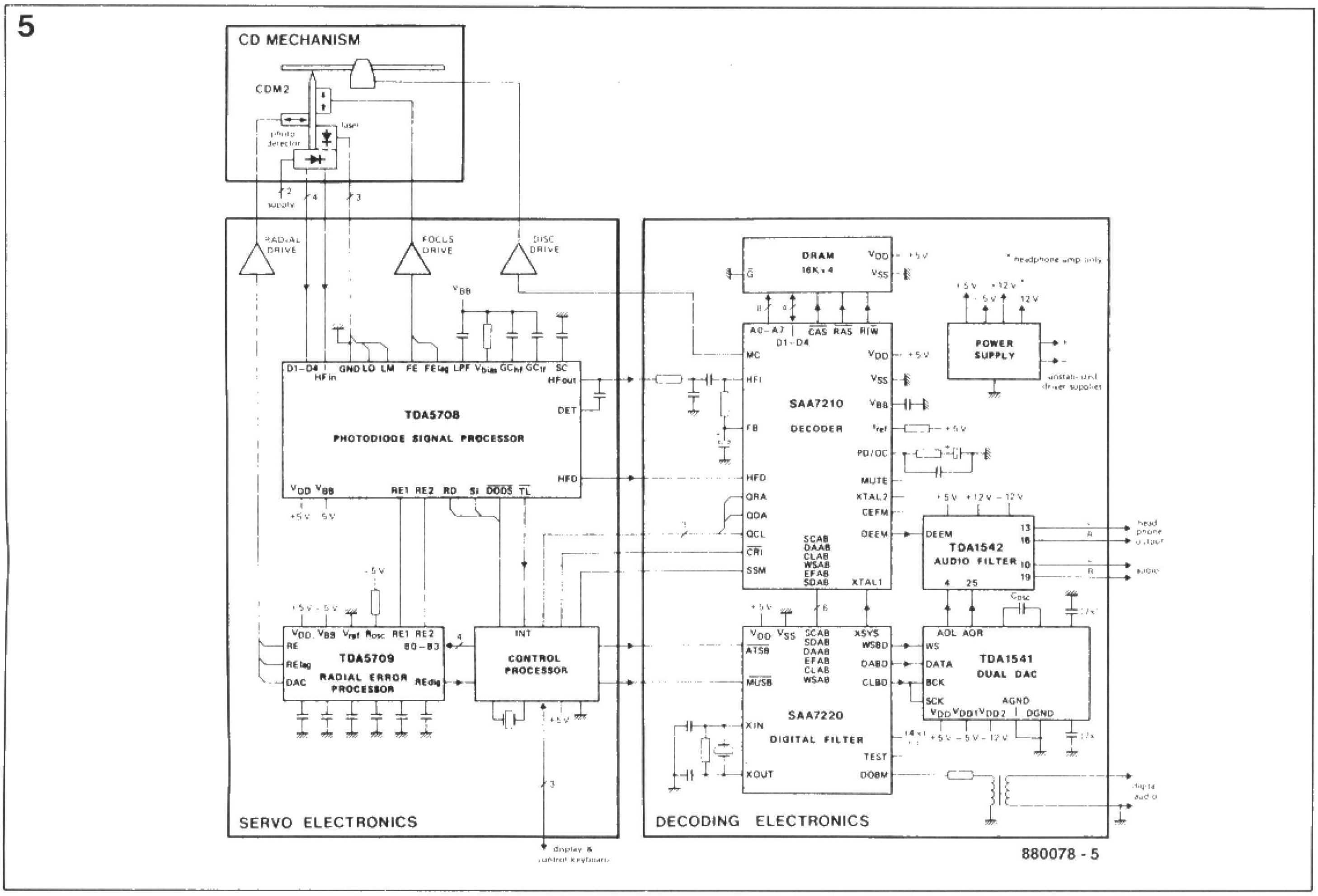



Fig. 5. Simplified circuit diagram of a complete CD player. All ICs are Valvo (Philips) products.

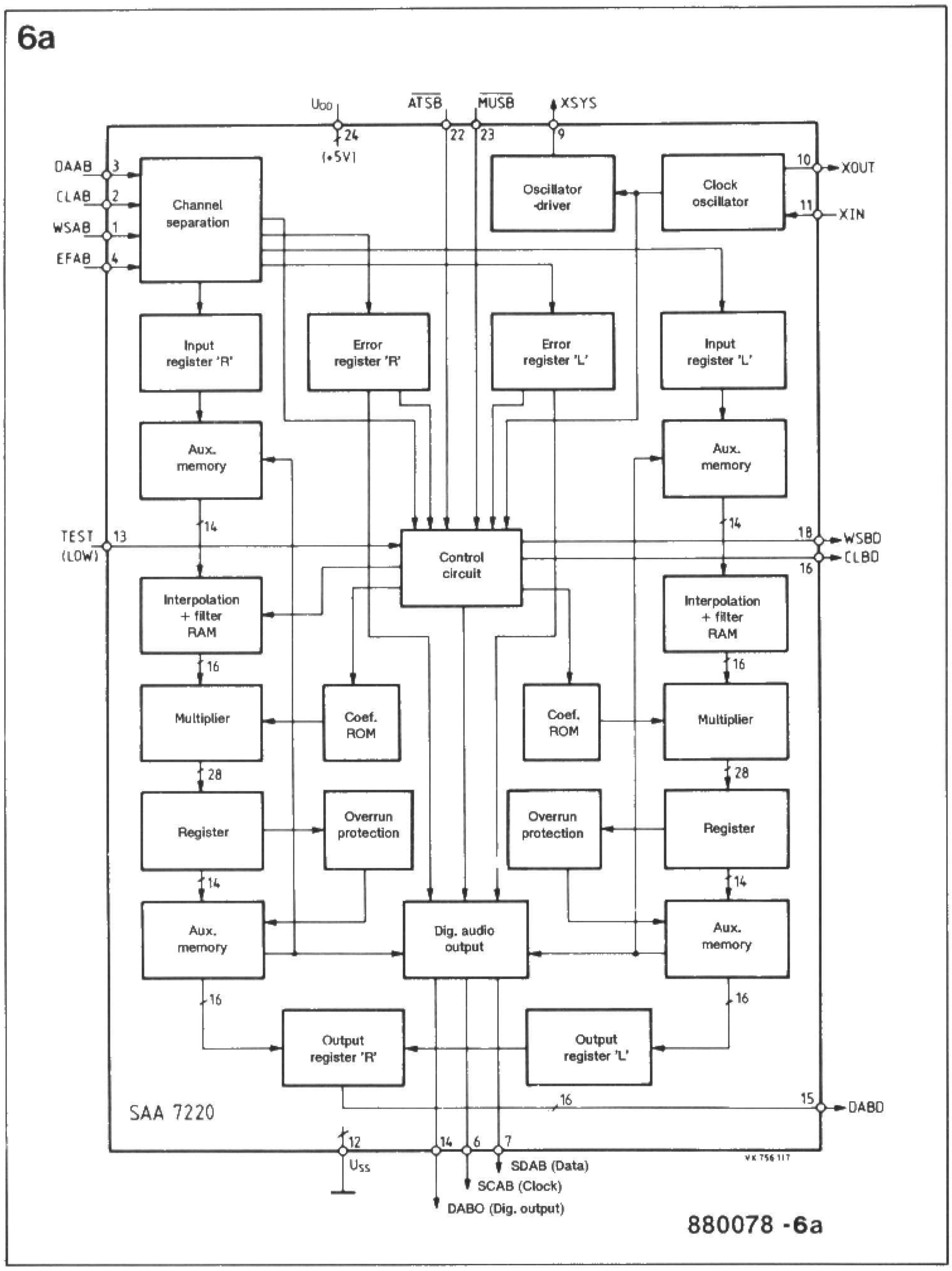



Fig. 6a. Digital oversampling filter Type SAA7220 is manufactured with an interface circuit for a digital output at pin 14.

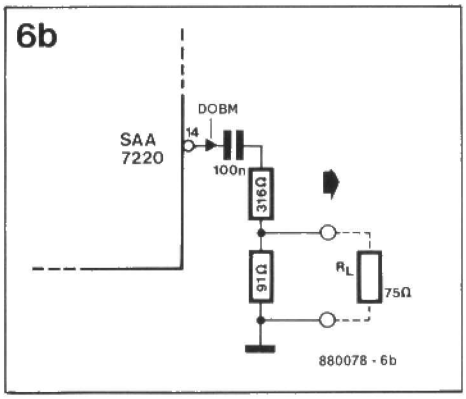



**Fig. 6b. Ancillary circuit to obtain a d.c.-free 75-ohm output of 500 mV$_{pp}$.**

**Table 1**

Electrical characteristics of Philips – Sony Format

**Output level:**
0.5 V$_{pp}$ ±20% into 75Ω ±1%
d.c. component: ≦50 mV

**Input level:**
≧200 mV

**Impedances:**
Source: 75Ω ±20%
Load: 75Ω ±5%
Cable: 75Ω ±35% (length ≦10 m)
75Ω ±5% (length ≧10 m)

**Table 2**

Cell sequence in preamble

| Preamble | Previous cell 0 | Previous cell 1 |
|---|---|---|
| 'B' | 11101000 | 00010111 |
| 'M' | 11100010 | 00011101 |
| 'W' | 11100100 | 00011011 |

to logic 0, but is the opposite when the bit to be transferred is logic 1. This explains how, in Fig. 1, the cell sequence is produced from the data signal, and which subsequently results in the biphase mark signal. This results in:

- a change of signal polarity after each bit;
- two changes of signal polarity for each logic 1.

The first four bits of a 32-bit word (bits 0 to 3) form the so-called preamble for the synchronization (see Fig. 2). This sync sample, which really only corresponds to the length of four data bits, does not represent a biphase code and contains no data. Yet, there are three types of sync sample in order to simultaneously identify words and blocks. The preamble is distinguished from data bits in that no two polarity changes occur at the edges of the bits. The logic state of the first section of the preamble is the opposite of that of the second part of the preceding bit, which is the parity bit (bit 31) of the preceding 32-bit word. The subsequent cell sequences of the preamble, consisting of eight successive logic states (four cells), are shown in Table 2.

The three preamble samples have the following meaning:

- 'B' marks a data word from channel 'A' (left-hand) stereo channel) that starts a block;
- 'M' marks a data word from channel 'A' that does not begin a block;
- 'W' marks a data word from channel 'B' (right-hand stereo channel); it may also be used for other channels (bit not 'A') in multi-channel systems.

Fig. 2 shows a preamble 'B' that starts at a leading edge.

## Format of word and blocks

For each channel sample, a 32-bit word called subframe is transferred—see Fig. 3. The first section contains the preamble (bits 0 to 3), followed by four bits auxiliary audio data (bits 4 to 7), and a 20-bit audio sample word (bits 8 to 27). This enables a resolution of the transfer standard of up to 24 bits per sample. The CD player needs only the 16 bits from LSB (bit 13) to MSB (bit 28); the unused bits (4 to 12) are made logic low.

The last section of the subframe contains the validity bit, which shows the receiver that the audio sample will not be used. This bit is set by the CD player in case of an error. Bit 29 contains subcode data from the CD player, such as text information. Bit 30 contains the channel status data. Finally, the parity bit ensures parity of all word bits, except sync sample bits 0 to 3.

The number of subframes in a frame corresponds to the number of channels. In a CD player, a frame contains a subframe for left-hand channel 'A' and one

7

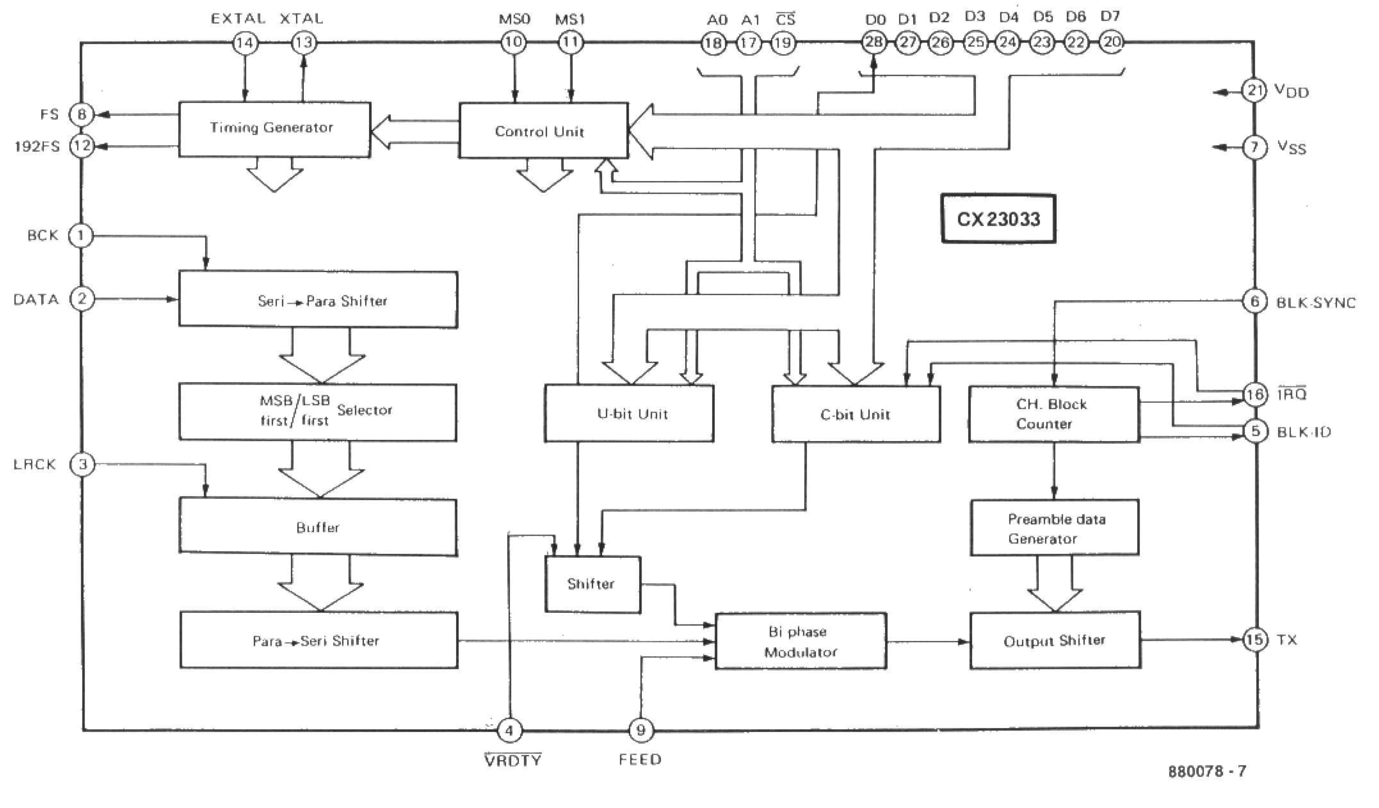



**Fig. 7. Block schematic of Sony's digital audio interface Type CX23033. This chip is not only suitable for use in CD players, but can also serve as output building brick in Digital Audio Taperecorders and PCM Tuners.**

8

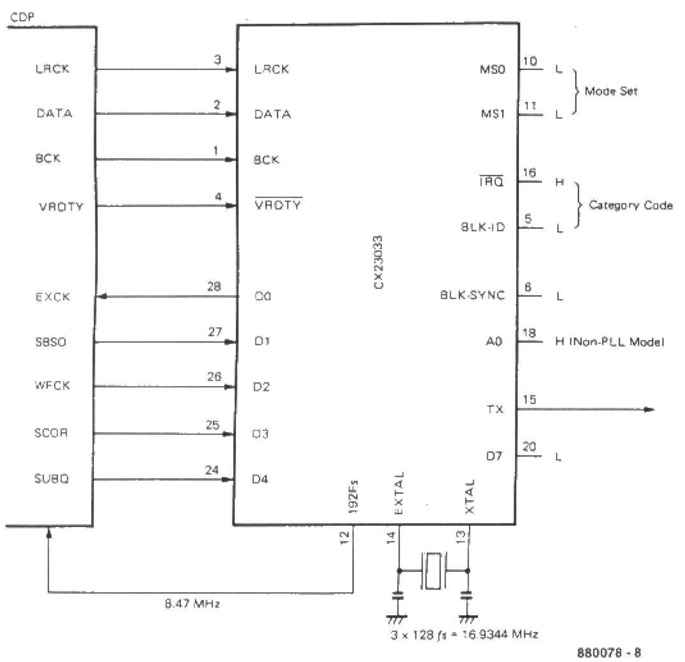



**Fig. 8. Connections between a CX23033 and a Sony CD player.**

9

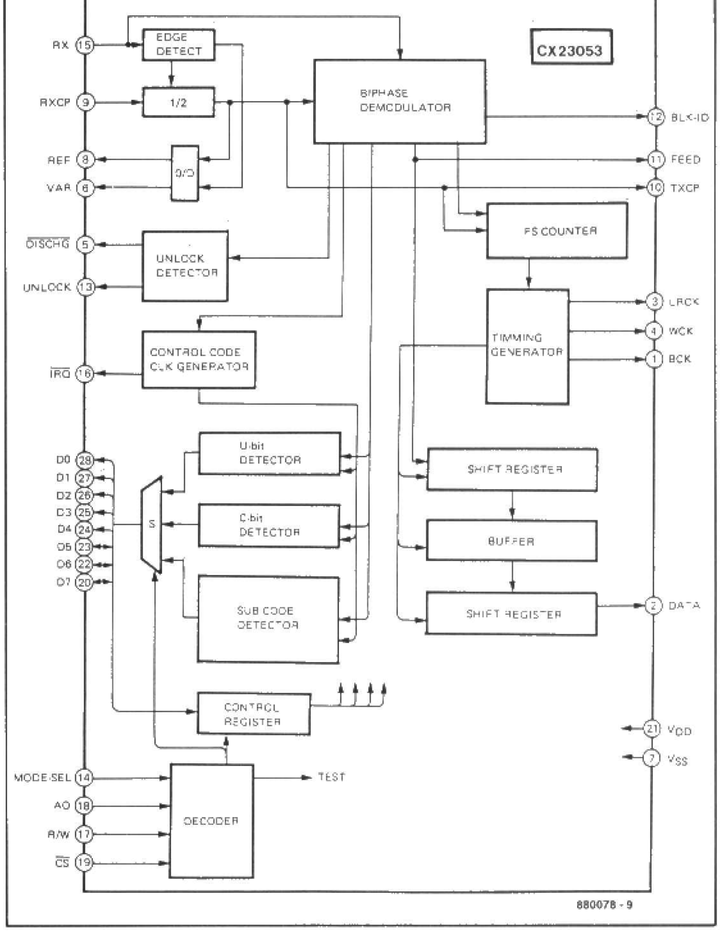



**Fig. 9. Block schematic of Sony's CX23053, a receiver building brick for the decoding of biphase mark signals.**

for right-hand channel 'B'. A block, commencing with preamble 'B', contains 192 frames—see Fig. 4. The transfer time of a frame corresponds to the period of the sampling rate of the signal source (in CD=44.1 kHz).

## Channel status and subcode information

One bit per subframe is used for the conveyance of channel status and subcode information. Since the channel status bits in the two subframes of a frame are identical, only 192 of such bits are used from each block. The first four of these are control bits. Bit 1 is logic high only in 4-channel operation. Bit 2 is 0 (reserved). Bit 3 is the copy-inhibit bit: when it is logic 1, copying can take place; when it is 0, copying is impossible. Bit 4 is the pre-emphasis bit (logic 1 for pre-emphasis).

Bits 5 to 8 are logic 0 (reserved). Bits 9 to 16 represent a category code, which can indicate three categories: (a) general 2-channel format (bits 9 to 16 = 0); (b) 2-channel CD format (bit 9 = 1); and (c) 2-channel PCM encoder—decoder format (bit 10 = 1). Bit 9 is set by the CD player.

The remaining status bits (17 to 192) are always 0.

The subcode bits may, if desired, be used by the CD manufacturer, but to date there are no consumer requirements for this. All that has been laid down so far is that the subcode bits be combined into blocks of 1176 bits for the introduction of a sync word that consists of at least 16 logic low bits.

## Hardware

Fig. 5 shows the simplified circuit diagram of a CD player with the extensively used batch of Valvo ICs. Of particular interest here is the digital oversampling filter (SAA7270) that operates in conjunction with the data decoder (SAA7210) at the input and the dual digital-to-analogue converter (TDA1541) at the output. This popular 16-bit 4-times oversampling system has the advantage that a simple Bessel filter of the 3rd order is sufficient as a low-pass section at the analogue output which is here formed by the TDA1542.

Less well-known is the advantage of Valvo's design in integrating the interface for the digital output in the digital filter, as shown in Fig. 6a. The DOBM (Digital Out Biphase Mark) signal is present at pin 14. Since pin 14 is the output of a 5-V NMOS IC with corresponding logic state (0.2 V or 4.8 V), it is necessary, in order to obtain the standard 500 mV output into 75 ohms, to connect it to the load via a 100 nF capacitor and a potential divider, as shown in Fig. 6b. As shown in Fig. 5, Philips uses a small transformer to couple pin 14 to the 75-ohms load.

The extra cost of a digital output in CD players that use the Valvo ICs is very small. Yet, CD players with this facility are rare. As has been shown, it is very simple, however, to add it at a later stage. In equipment with Japanese ICs, it is, unfortunately, not quite so simple or inexpensive. However, Sony has brought a Digital Audio Data Modulating and transmitting IC, the Type CX23033, on the market, which is suitable for use not only in CD players, but also in DATs and PCM tuners.

For digital audio taperecorders—DATs—Sony has developed new LSIs, of which one, the 64-pin SMD IC Type CXD1146Q, assumes the sending and receiving in Philips-Sony Format.

On the other hand, the CX23033, whose block schematic is shown in Fig. 7, offers four different modes of operation. For example, in the DAT mode, it is possible to set the copy-inhibit bit (bit 3 as discussed earlier) via pin 22 (D6).

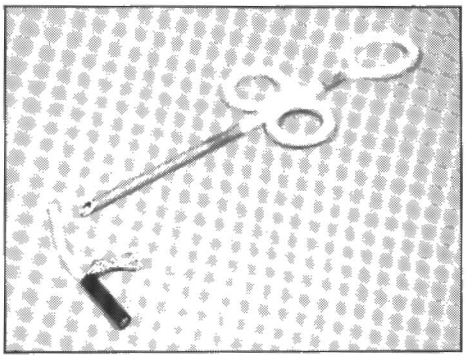
The data to be transferred are applied serially to pin 2 and from there transmitted in Philips—Sony Format to pin 15.

Fig. 8 shows an example of connecting the CX23033 with a so-called one-chip CD that uses the Sony CX23033 with 48 clock pulses per sample.

The matching IC at the receiver side of the digital audio connection is the CX23053, whose block schematic is shown in Fig. 9. This chip demodulates and evaluates the biphase signal, after this has been synchronized with the aid of an external PLL. It then delivers the serial audio data to the Data output (pin 2), and the subcode and control data to other relevant outputs. The copy inhibit bit is available at pin 26 for further use.

A comparable receiver building brick can be constructed from Valvo's SAA7220 and TDA1541. Although this has been developed, it has at the time of writing (April 1988) not yet reached the market.

## NEW PRODUCTS



### Lead extractor

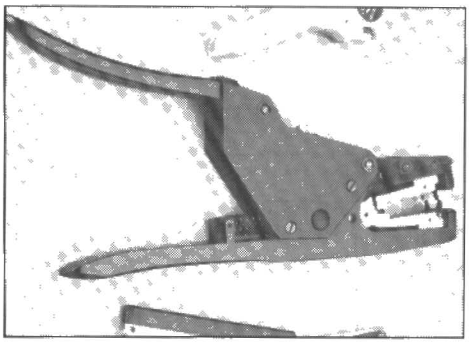
A new lead extractor ejects the lead wire of shielded or coaxial cable through the braid. The action of the tool is similar to that of a hypodermic needle: the sharp tip of the blade penetrates the braided shield and the plunger ejects the lead wire through the braid wall. The tool is available for inner lead wires up to 3.3 mm diameter.

**Rush Wire Strippers • Unit M • Hunting Gate • ANDOVER SP10 3LU • Telephone (0264) 51347/8.**

### Silence is golden

The ultra-quiet Master Mite Heat Gun is designed for continuous operation where instant, flameless heat is required such as shrink tubing, solder preforms, and surface drying. The unit has three interchangeable snap-in heating elements to give a temperature range from 260 °C to 427 °C.

**Master Heat Tools • Unit M • Portway Industrial Estate • ANDOVER SP10 3LU • Telephone (0264) 51347/8.**

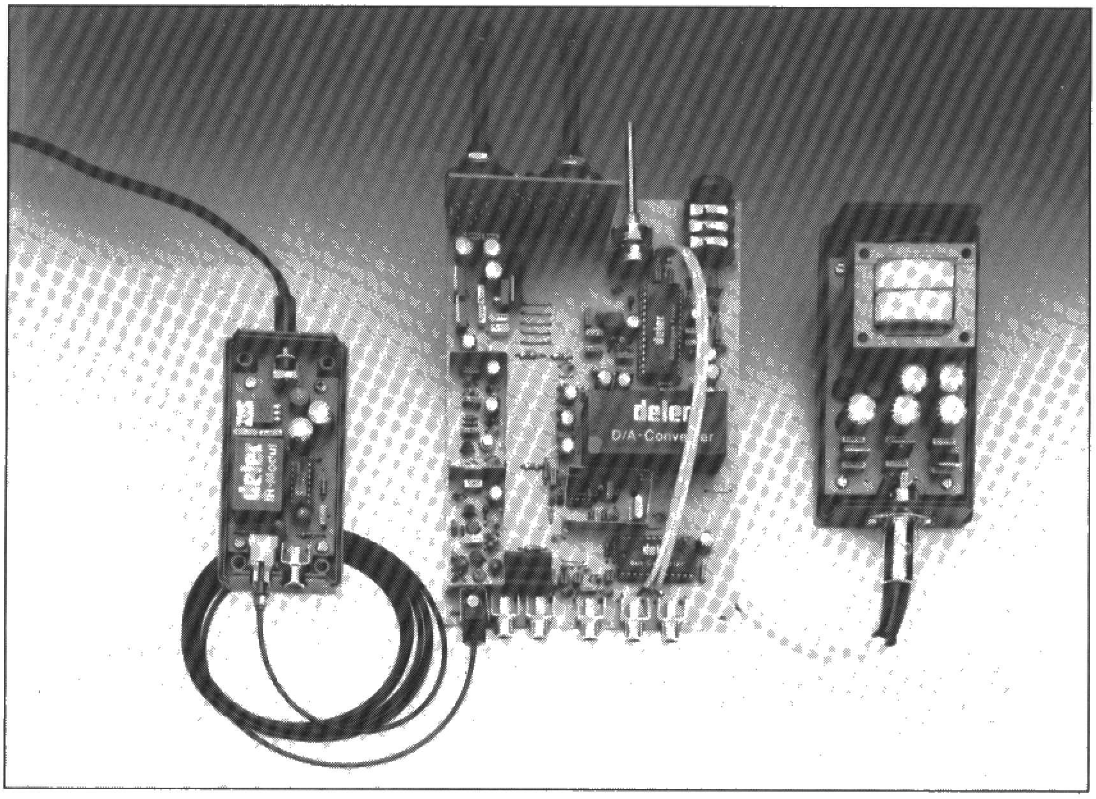



### Multi-function wire stripper

The Mega-Strip from Toolrange will strip electrical wires and cable from 1 mm² to 16 mm², insulated with PVC, vinyl, polyethelene, or almost any other common material.

**Toolrange Ltd • Upton Road • READING RG3 4JA • Telephone (0734) 29446.**

# DIGITAL OPTICAL RECEIVER



**Last month's design of a digital optical transmitter for compact disc players is completed with a receiver and a converter board offering a true 2-channel 16-bit DAC with quadruple oversampling. Like the transmitter, the present design is based on recently introduced high-quality audio ICs which come as simple-to-use modules.**

The digital-to-analogue converter board has an input for the optical receiver, and two switchable coax cable inputs for CD signals to the Philips/Sony standard. The converter board provides two line outputs, two adjustable headphone outputs, and a monitor output which enables the digital signal to be fed to other equipment.

A phase-locked loop (PLL) in the receiver ensures synchronization to the clock pulses. Locking is indicated by a LED. A further LED indicates automatical activity of the on-board de-emphasis circuitry.

**DIGITAL OPTICAL RECEIVER: TECHNICAL CHARACTERISTICS**

| | |
|---|---|
| **DAC:** | |
| Frequency range: | 2 Hz — 20 kHz |
| Amplitude linearity: | 20 Hz — 20 kHz: ±0.1 dB |
| Signal-to-noise ratio: | >102 dB |
| Dynamic range: | >96 dB |
| Channel separation: | >100 dB |
| Distortion: | <0.01% (1 kHz) |
| Attenuation outside pass-band: | > 55 dB (24.1 kHz) |
| **Headphone amplifier:** | |
| Output impedance: | 150 Ω |
| Load impedance: | 8 Ω — 2000 Ω |
| Output power: | max. 39 mW in 32 Ω |
| | max. 50 mW in 600 Ω |
| Frequency range: | 20 Hz — 20 kHz ±1 dB |
| Gain balance: | ±0.5 dB |
| Signal-to-noise ratio: | >93 dB |
| Dynamic range: | >90 dB |
| Distortion (incl. noise): | <0.003% ($Z_L$=600 Ω) |
| Intermodulation distortion: | <0.003% ($Z_L$=600 Ω) |
| Channel separation: | >75 dB ($Z_L$=600 Ω) |
| **Inputs:** | |
| System 1 (cinch/phono): | 0.6 $V_{pp}$; $Z_i$=75 Ω |
| System 2 (cinch/phono): | 0.6 $V_{pp}$; $Z_i$=75 Ω |
| Optical receiver: | −15 — −23 dBm |
| **Outputs:** | |
| Stereo (line; 2× phono/cinch) | 2 $V_{rms}$ in 100 Ω |
| Headphones: | impedance 8 Ω — 2000 Ω |
| Digital (phono/cinch) | 0.6 $V_{pp}$; $Z_o$=75 Ω |

## Circuit descriptions

**Optical receiver.**

The receiver is connected to the fibre optic cable by means of the Motorola plug as discussed last month. Properly installed, this plug automatically presses the end of the fibre optic cable onto the face of the photodiode. With reference to the circuit diagram of Fig. 1, the modulated light intensity in the fibre optic cable is translated into a base current for $T_6$ by reverse-biased photodiode $D_{10}$. Transistors $T_6$ and $T_7$ form a low-noise cascade in which $T_7$ is operated in a common base configuration. Base

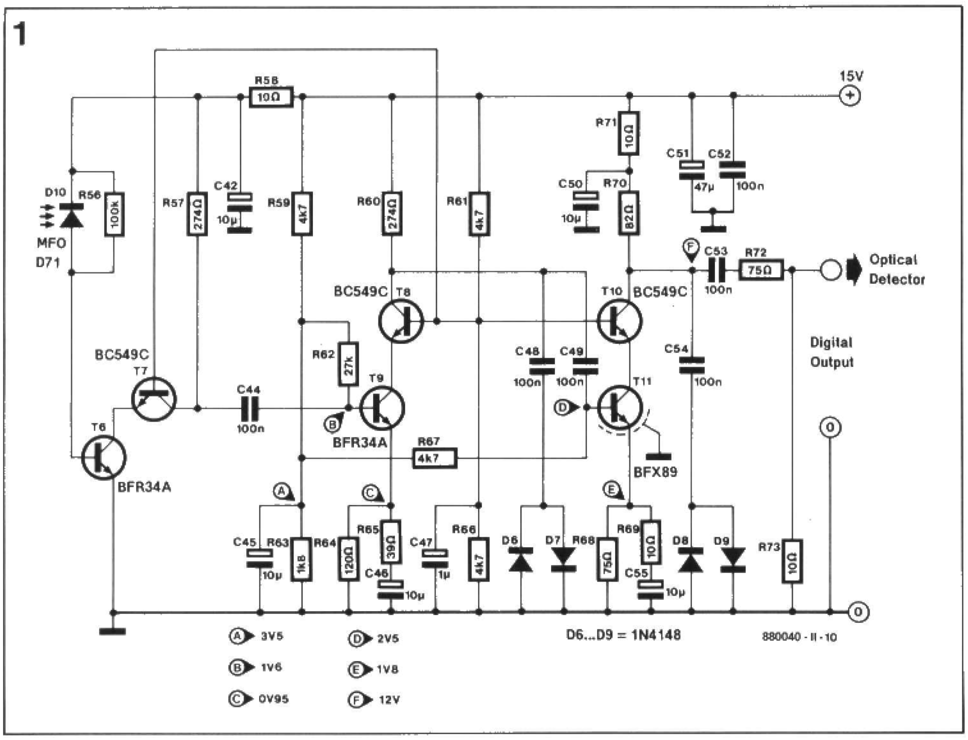


Fig. 1. Circuit diagram of the optical receiver.

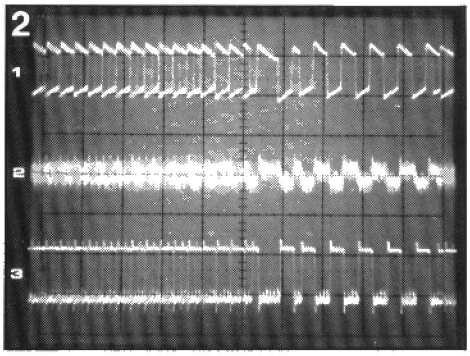


**Fig. 2. Some signal waveforms. 1. digital output signal of a CD player (CD960 from Philips) (0.5 V/div); 2. output signal of photodiode in optical receiver (5 mV/div); 3. output signal of optical receiver (0.1 V/div). Timebase setting: 1 $\mu$s/div.**

decoupling and bias setting is arranged in common for $T_7$, $T_8$ and $T_{10}$ by $C_{47}$ and potential divider $R_{61}$-$R_{66}$ respectively.

The next high-gain amplifier stage is cascade $T_8$-$T_9$, which drives limiter $D_6$-$D_7$. Then follow a further cascade, $T_{10}$-$T_{11}$, and yet another limiter, $D_8$-$D_9$.

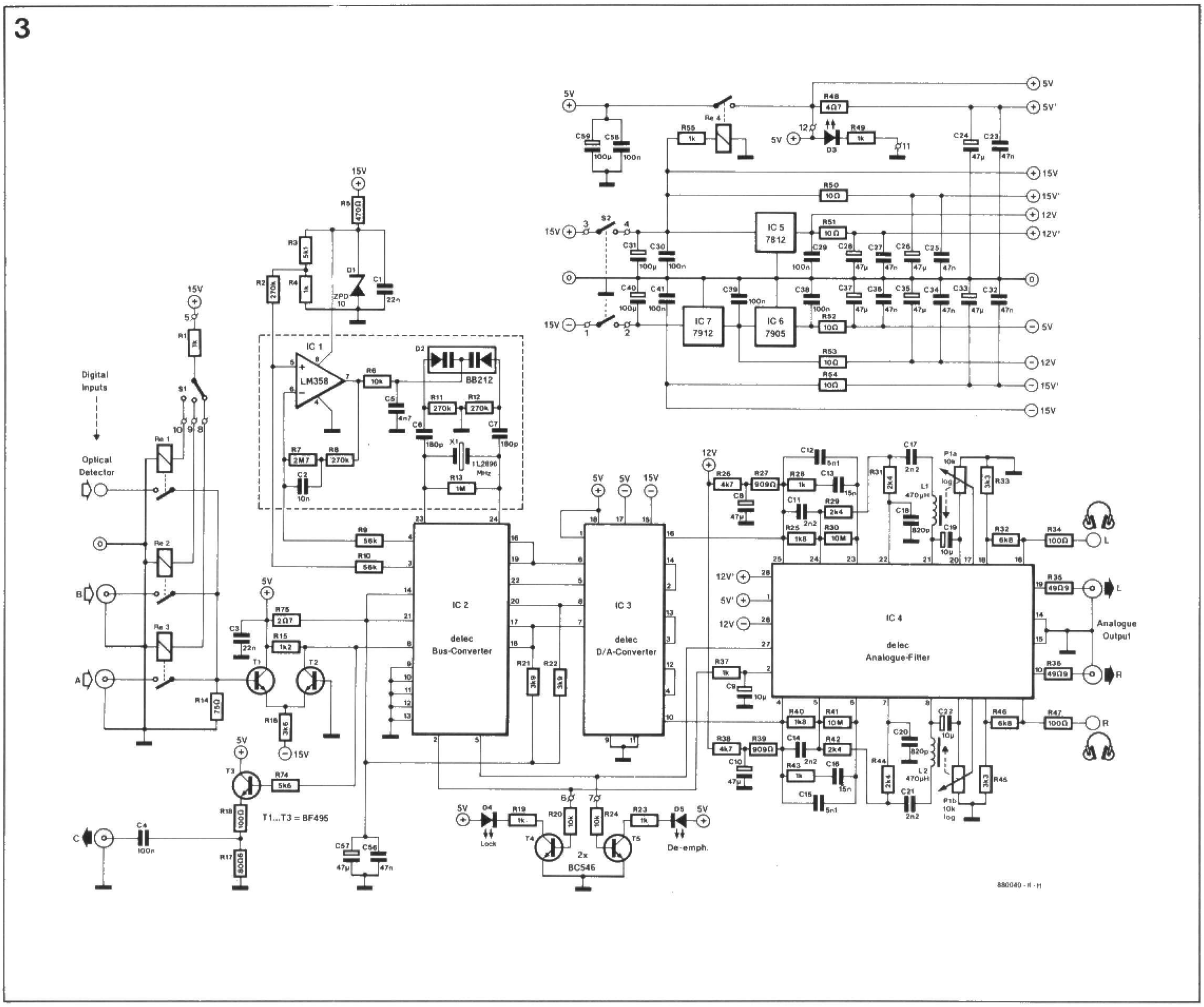


Fig. 3. Circuit diagram of the high-quality digital-analogue converter.

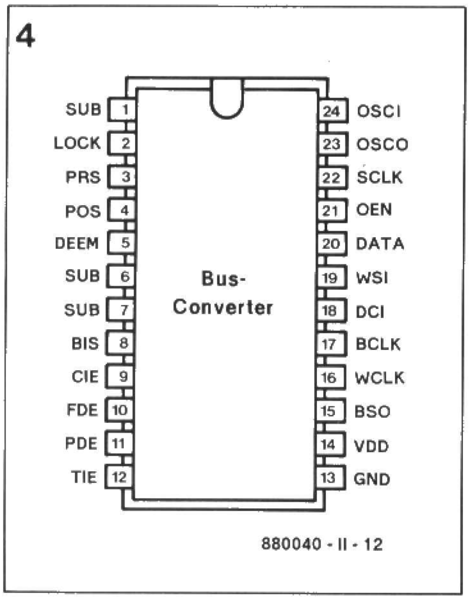



**Fig. 4. Pinning of the bus converter chip.**

Waveforms at various points in the amplifier are shown in the oscillograms of Fig. 2. The output signal is a square wave that may be fed to other audio equipment with a digital input.

**16-bit digital-to-analogue converter.**

Figure 3 shows the circuit diagram of this part of the digital optical receiver. The relays at the input of the DAC circuit are energized via rotary switch $S_1$, and select between 3 digital inputs, one of which is driven by the optical receiver discussed above. The first transistor in the input amplifier, $T_1$, is matched to the impedance of the coax cable by means of 75 Ω resistor $R_{14}$. The digital audio signal is raised in $T_2$, and fed to the input of bus converter $IC_2$ as well as to digital output buffer $T_3$, which supplies an AC coupled signal of 500. . .600 $mV_{pp}$ when terminated in the required impedance of 75 Ω.

A block diagram of the bus converter chip from Delec is, unfortunately, not available, but the pin functions are listed in Table 2. The chip converts the serial audio signal to the Philips/Sony standard into the so-called $I^2S$ bus format ($I^2S$: *Inter-IC sound*). This is used in conjunction with a serial databus for interconnecting CD chips from Valvo/Mullard (Philips), who propose it as a standard for their range of A-D and D-A converters, signal processors, digital filters, interfaces and error correction circuits.

The bus converter is coupled to an external PLL to ensure synchronization to incoming data. Frequency correction of the crystal oscillator is effected by varicap $D_2$ and loop amplifier $IC_1$. LED $D_4$ lights when the PLL is locked. The mute function of the analogue filter IC is coupled to the lock indicator to prevent audible interference on the audio output when the converter is out of lock owing to corrupted input data or other errors.

**Table 2.**

Delec Bus Converter: pin descriptions.

| PIN | FUNCTION | |
|---|---|---|
| 14 | VDD: | Supply voltage (+5 V; 100 μA) |
| 8 | BIS: | Biphase Input Signal (Philips-Sony-Format) |
| 20 | DATA: | Data Output Signal (max. 4 MHz) |
| 22 | SLCK: | System Clock Output (typ. 11.2896 MHz) |
| 17 | BCLK: | Bit Clock Output (typ. 2.822 MHz) |
| 16 | WCLK: | Word Clock Output (typ. 44.1 kHz) |
| 15 | BSO: | Block Synchronization Output (typ. 229.69 Hz) |
| 24 | OSCI: | Clock Oscillator Input (typ. 11.2896 MHz) |
| 23 | OSCO: | Clock Oscillator Output (typ. 11.2896 MHz) |
| 3 | PRS: | Phase Reference Signal (max. 7 MHz) |
| 4 | POS: | Phase Output Signal (max. 7 MHz) |
| 2 | LOCK: | Signal Lock Control (high when PLL locks, +5 V/2 mA) |
| 5 | DEEM: | De-emphasis Control (+5 V/2 mA) |
| 18 | DCI: | Data Clock Input (max. 4 MHz, connect to BCLK) |
| 19 | WSI: | Word Select Input (max. 50 kHz, connect to WCLK) |
| 6-7 | SUB: | Subcode-Outputs |
| 21 | OEN: | Output Enable (connect to +5 V) |
| 10 | FDE: | Frequency Detector Enable (connect to GND) |
| 9 | CIE: | Capacitive Input Enable (connect to GND) |
| 11 | PDE: | Phase Detector Enable (connect to GND) |
| 12 | TIE: | Test Input Enable (connect to GND) |

De-emphasis and subcode data detection is internal to $IC_2$. The de-emphasis indicator, $D_5$, and the appropriate filter components in analogue filter chip $IC_4$ are automatically switched on when the received programme material contains digital de-emphasis markers.

The bus converter feeds 4 signals to the oversampling filter in DAC $IC_3$: serial data; system clock (11.2896 MHz); bit clock (2.8224 MHz); and word select (44.1 kHz). The block diagram of the DAC from Delec is shown in Fig. 5. The chip is a true dual converter, which means that it does not multiplex incoming signals with all the associated problems of phase shift between channels. The chip is also remarkable for its extremely fast signal response. The internal quadruple oversampling filter makes it possible to use relatively simple filters at the analogue outputs. Apart from this, quadruple oversampling is also beneficial in that it avoids sound colouring due to ringing and poor gain flatness caused by analogue filters with steep slopes. The digital filter is also capable of ''recovering'' up to eight corrupted samples on the basis of interpolation.

The output filter is set up around a chip that ranges among the best available in its class. It comprises two sets of 5 ultra-low-noise operational amplifiers designed for CD and DAT applications. The attainable signal-to-noise ratio is about 110 dB, while the maximum output amplitude is 2 $V_{rms}$. The internal structure of the Delec analogue filter chip is given in Fig. 6.

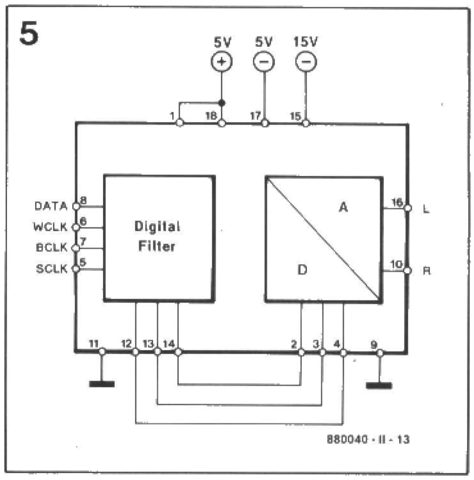



**Fig. 5. Internal structure of the 16-bit dual digital analogue converter with built-in quadruple oversampling filter.**

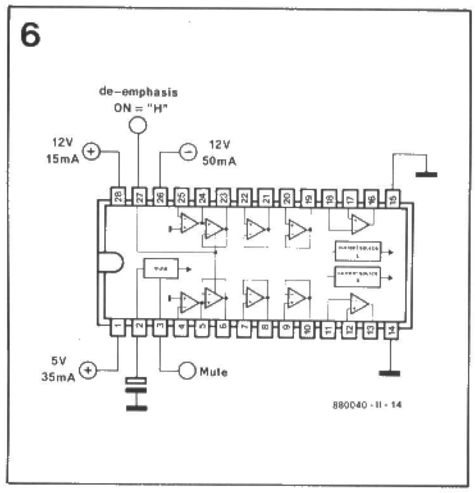



**Fig. 6. Internal structure and pinning overview of the analogue filter module.**

7

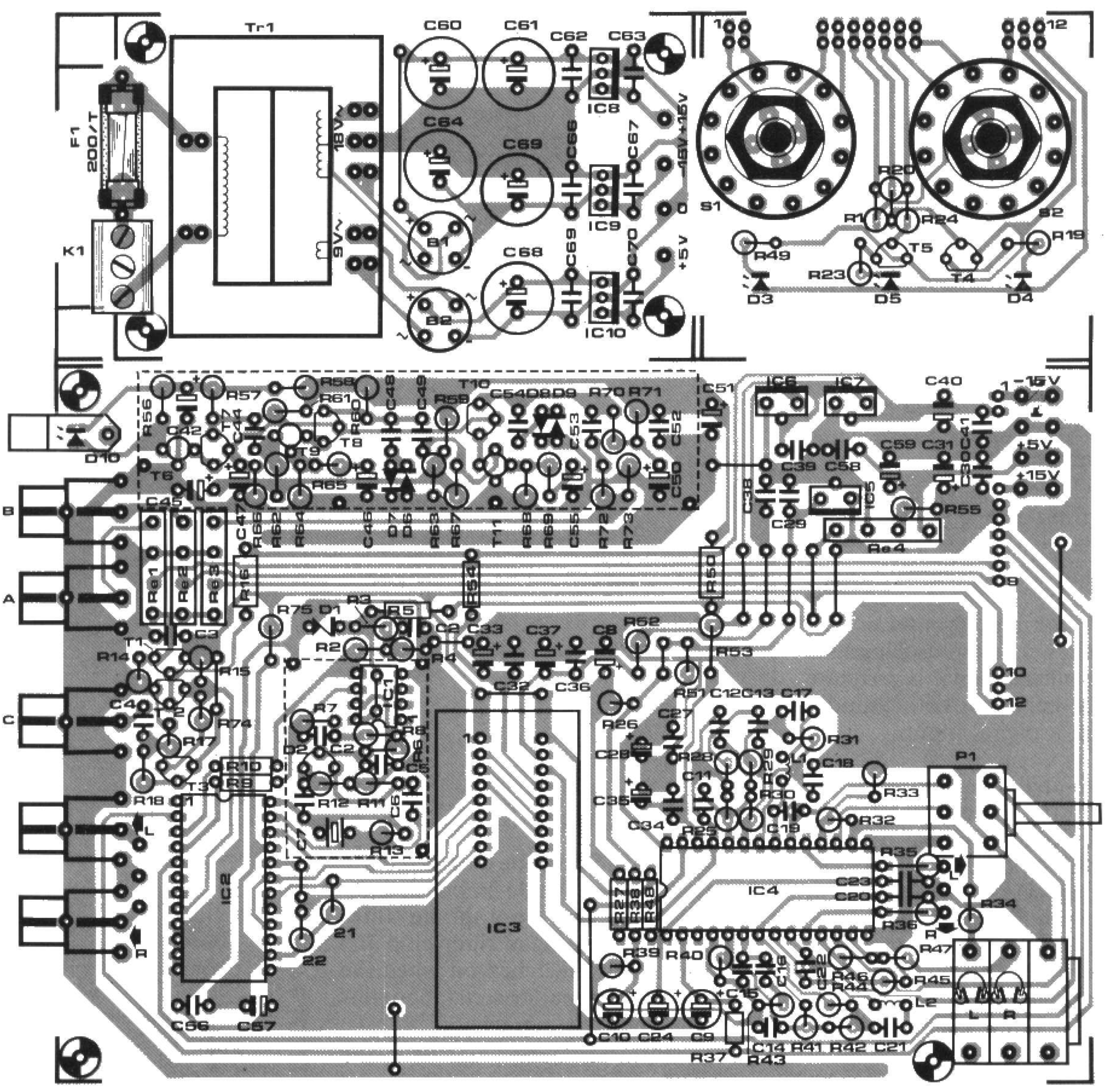


**Fig. 7. The printed circuit board for this project must be cut in three to enable building the optical receiver plus converter, the AC section of the power supply, and the vertically mounted controls and indication board, as separate units.**

**Parts list**

Resistors (±5%):

R1;R19;R23;R49;R55 = 1K0
R5 = 470R
R6;R20;R24 = 10K
R48 = 4R7
R50;R51;R52;R53;R54;R58;R69;R71;R73 = 10R
R59;R61;R66;R67 = 4K7
R62 = 27K
R63 = 1K8
R64 = 120R
R65 = 39R
R70 = 82R
R74 = 5K6
R75 = 2R7

Resistors (±1%):

R2;R8;R11;R12 = 270K
R3 = 5K1
R4;R28;R37;R43 = 1K0
R7 = 2M7
R9;R10 = 56K
R13 = 1M0
R14;R68;R72 = 75R
R15 = 1K2
R16 = 3K6
R18;R34;R47 = 100R
R17 = 80R6
R21;R22 = 3K9
R25;R40 = 1K8
R26;R38 = 4K7
R27;R39 = 909R
R29;R31;R42;R44 = 2K4
R30;R41 = 10M
R32;R46 = 6K8
R33;R45 = 3K3
R35;R36 = 49R9
R56 = 100K
R57;R60 = 274R
P1 = 10K stereo logarithmic potentiometer

Capacitors:
(MKT 5% unless otherwise noted; pitch 5 mm)

C1;C3 = 22n
C2 = 10n
C4;C29;C30;C38;C39;C41;C44;C48;C49;
C52;C53;C54;C58;C62;C63;C66 = 100n
C67;C69;C70 = 100n
C5 = 4n7
C6;C7 = 180p ceramic
C8;C10;C24;C26;C28;C33;C35;C37;
C51;C57 = 47µ; 25 V
C9;C19;C22;C42;C45;C46;C50;C55 = 10µ; 25 V
C11;C14;C17;C21 = 2n2
C12;C15 = 5n1
C13;C16 = 15n
C18;C20 = 820p polystyrene/styroflex
C23;C25;C27;C32;C34;C36;C56 = 47n
C31;C40;C59 = 100µ; 25 V
C47 = 1µ0; 25 V
C60;C61;C64;C65;C68 = 1000µ; 25 V

Semiconductors:

B1;B2 = B80C1500 bridge rectifier 80 V; 1.5 A
D1 = 10 V; 400 mW zener diode
D2 = BB212 (Maplin; Cirkit; Bonex)
D3 = green LED
D4 = yellow LED
D5 = red LED
D6;D7;D8;D9 = 1N4148
D10 = MFO D71 (Motorola; U.K. distributors are listed on InfoCard 507; *EE* April 1987).
IC1 = LM358
IC2 = bus converter *
IC3 = DAC module *

CONTINUED OVERLEAF

**Power supply**

The DC part of the power supply circuit shown in the top right-hand corner of Fig. 3 may appear complex at a first glance, but is entirely conventional as it is set up around voltage regulators from the familiar 78 and 79 series. The mains transformer and rectifier circuits are not shown, because these are accomodated on a separate PCB.
The 15 VDC inputs of the converter board are connected to a conventional symmetrical supply, whose circuit diagram is shown in Fig. 8. Relay $Re_4$ ensures that the ±15 V is always applied to the circuit before +5 V.

## Components

It will be clear that this project is intended for audio enthusiasts striving for perfection. As a matter of course, all components in the digital and AF sections of the optical transmitter and receiver should be of the highest possible quality.
Foil capacitors are preferably 5% MKT types, or, when available, polystyrene (Siemens: styroflex) versions with a tolerance of 2%. $C_{12}$ and $C_{15}$ in the analogue output filter can be made from parallel combinations of a 4n7 MKT capacitor and a 390 pF styroflex type when 5n1 is not available.

## Configuring and building the circuit

Depending on the application, the circuit need not be built up completely as shown in the circuit diagrams. For instance, not all three inputs on the converter board may be needed, and it should be fairly evident which components may be omitted. The optical receiver may not be required at all when a short length of coaxial cable is used for carrying the digital CD signal to the active loudspeaker.
When the D-A converter is fitted in an active loudspeaker, it need, of course, be configured for one channel only. All parts that form the analogue filter of one channel may then be omitted, with the exception of the resistors at the chip input (upper channel: $R_{25}$, $R_{26}$ and $R_{27}$; lower channel: $R_{38}$, $R_{39}$, $R_{40}$.

The component mounting plan for ready-made board Type 880040-2 shows that this must be cut in three to separate the power supply, switch/indication board, and the main board. Experienced constructors should have no difficulty populating the board as indicated by the component overlay and parts list. It is strongly recommended to use high-quality sockets to hold the modules.
The mounting of the small controls PCB onto the main converter board, as well as other constructional details are apparent from the introductory photograph. Metal screens are fitted to prevent digital interference in sensitive sections of the circuit. The shielding wires of the stereo line cable on the board may only be connected to ground at the side of the phono sockets.

*Gb*

$IC_4$ = analogue filter module *
$IC_5$ = 7812
$IC_6$ = 7905
$IC_7$ = 7912
$IC_8$ = 7815
$IC_9$ = 7915
$IC_{10}$ = 7805
$T_1$;$T_2$;$T_3$ = BF495
$T_4$;$T_5$ = BC546
$T_6$;$T_9$ = BFR34A (C-I Electronics)
$T_7$;$T_8$;$T_{10}$ = BC549C
$T_{11}$ = BFX89 (Cricklewood)

* Delec Elektronik GmbH • Dieselstrasse 30 • 6352 Obermörlen • West Germany. Telephone: +49 (6002) 1430.

Miscellaneous:

$F_1$ = fuse 250 mA delayed action; with PCB mount holder.
$L_1$;$L_2$ = 470μH miniature choke.
$Re_1$ . . . $Re_4$ incl. = Günther Type 3570 1331 053. W. Günther GmbH • Virnsberger Strasse 51 • D8500 Nürnberg 82. Telephone: +49 (911) 65521. Telex: 622351 wigu d.
$S_1$;$S_2$ = rotary switch for PCB mounting.
$Tr_1$ = mains transformer for PCB mounting: 2 × 18 V/150 mA, 7.5 V/350 mA.
$X_1$ = quarz crystal 11.2896 MHz.
1 off 6.3 mm stereo headphone socket for PCB mounting.
5 off gold-plated phono sockets for PCB mounting.
PCB 880040-2 (see Readers Services page).

Note: constructors are advised that a range of high-quality passive components for audio applications is available from AudioKits Precision Components (see advertisement elsewhere in this issue).

8

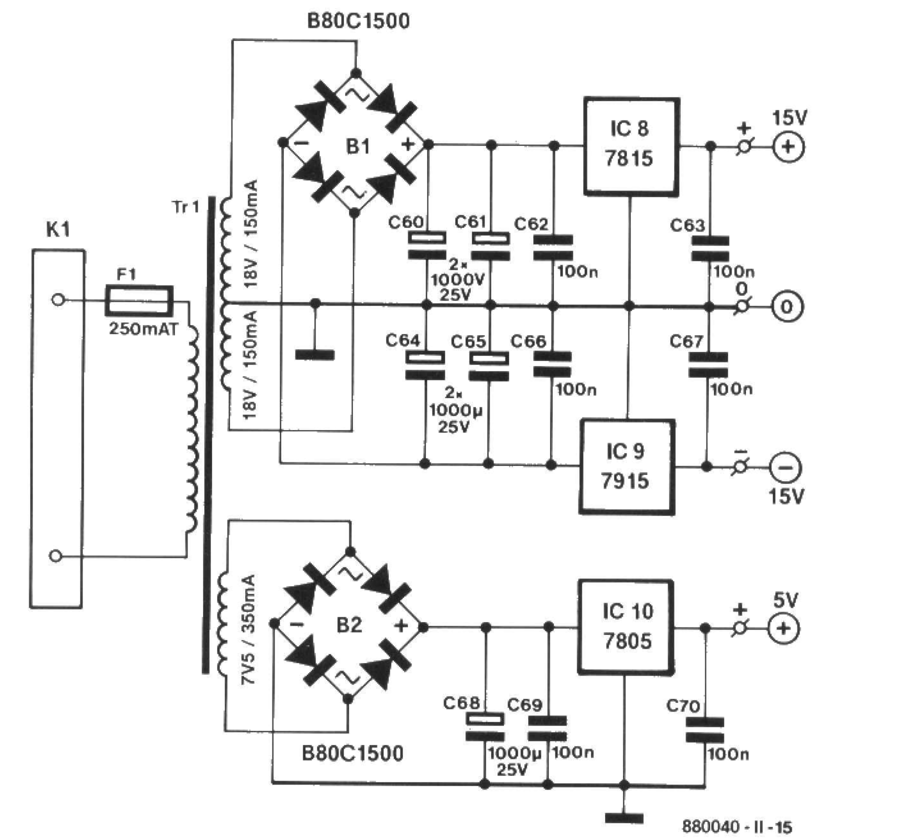
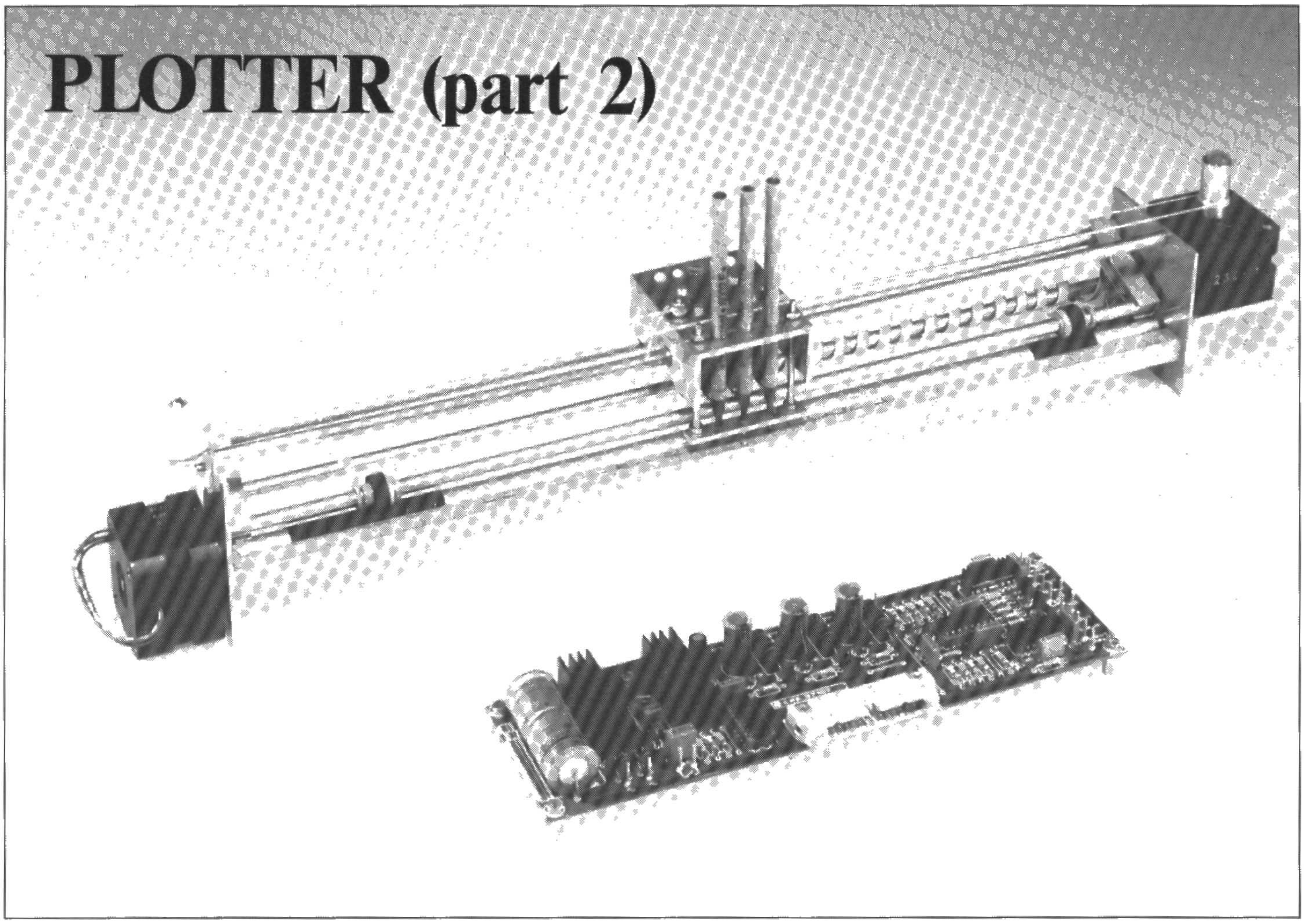



Fig. 8. This power supply for the digital optical receiver is fitted on a separate PCB.

# PLOTTER (part 2)



**No hardware without software, and vice versa. In this month's final instalment we lend a hand to all constructors of the plotter who are eager to write control software, but need general algorithms, flow diagrams and elementary programming procedures as guidance for tailoring the communication patch between their computer, available graphics programs, and the plotter.**

Before attempting to write a plotter interface program, it is necessary to acquire a basic understanding of computer control (*software/hardware*) in combination with graphics (or, more specifically, *drawing*). An algorithm needs to be devised for translating graphics information (on screen or in any form of memory) to actual pen positioning commands. The low-cost plotter described last month has no "on-board" intelligence, and must, therefore, be controlled at the bit level by the computer. In order to obtain reasonable drawing speed, it is necessary to write part of the control program in machine language, which accepts commands or command strings from a line editor, and translates these into pen movement commands by actuating the relevant control lines on the plotter interface board.

The bit assignment in the plotter control word is shown in Fig. 9. A stepper motor performs a full or half step, depending on the logic level of bit 2, on each positive transition of the clock signal (bit Ø). The clock pulse must remain logic high for at least 10 μs. Straight lines can be drawn by actuating the X or Y motor alone. Lines under an angle of 45° are drawn when the motors are actuated simultaneously. When both motors are actuated, but one is operated in the full step mode, and the other in the half-step mode, the slant angles become 26°34' or 63°27', corresponding to the tangent of 0.5 and 2, respectively.

## Elementary routine

A number of routines and algorithms are given below to provide a basis for developing one's own software. It should be noted that the information given is intended as guidance for those who have little or no experience in handling computer graphics. It is beyond doubt that there are other, perhaps more efficient, ways of controlling the plotter, but the methods outlined here have the advantage of being illustrative and relatively simple to put in practice on a particular computer system.

The suggested elementary routine does what its name implies: it provides control of the most fundamental capabilities of the plotter. Depending on the structure of the 8-bit control word sent along as a parameter, a single full or half step is performed in the X or Y direction, and/or a particular pen is selected. Bits Ø and 3 determine which motor, or which motors, is or are actuated. A step is performed by the relevant motor when the associated clock bit goes logic low. Direction of travel and full/half-step operation are controlled by the remaining four bits.

9

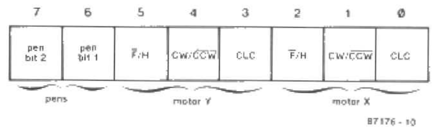



**Fig. 9. Bit assignment in the plotter control word.**

10

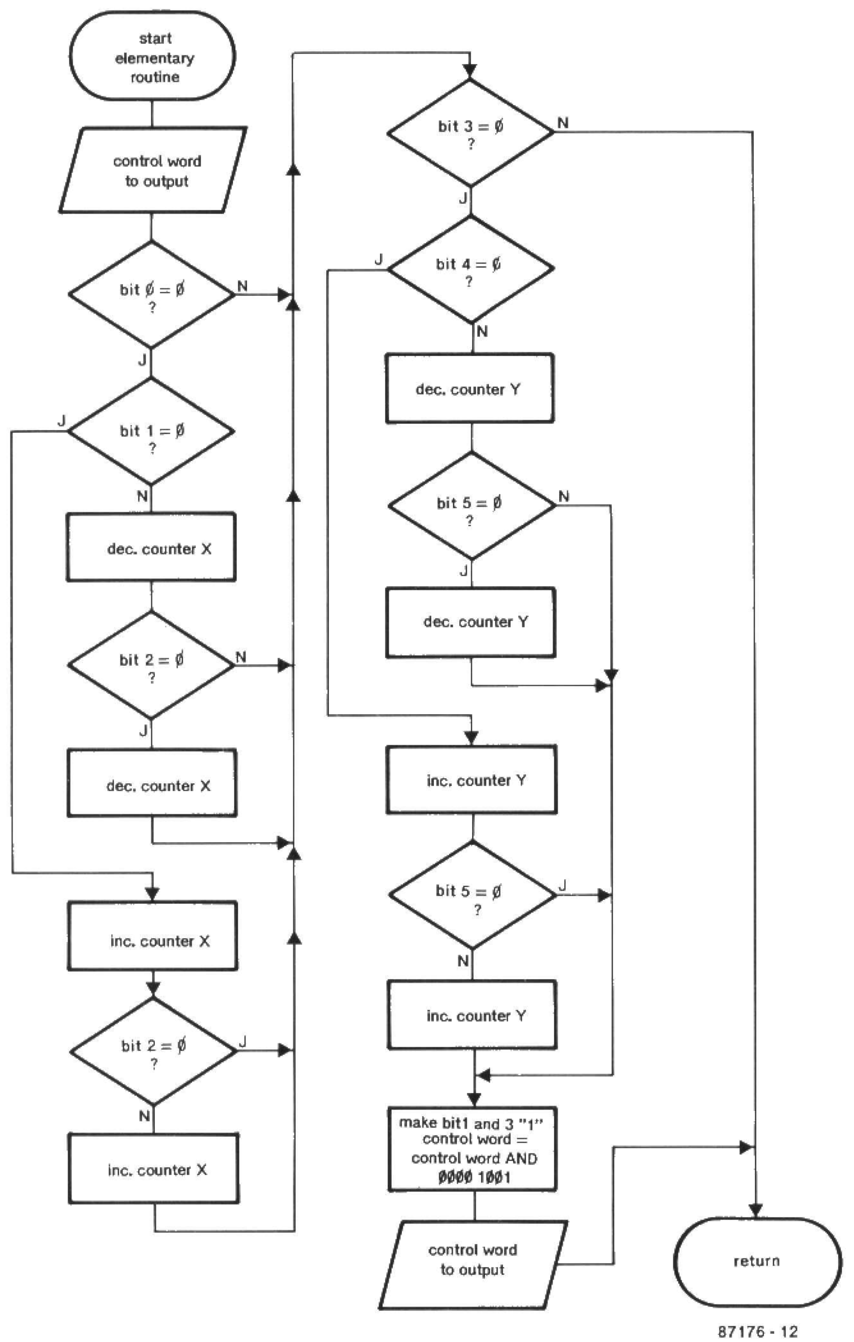



**Fig. 10. Flow chart of the elementary routine. Instantaneous X and Y coordinates are stored in 16-bit counters.**

11

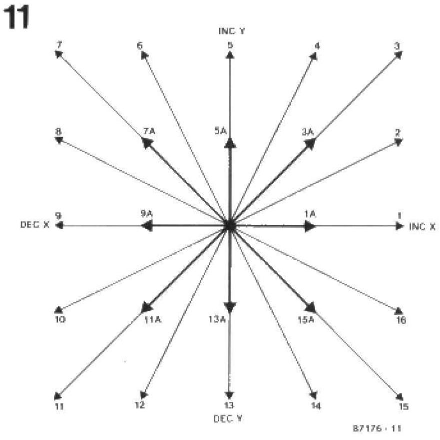



**Fig. 11. Oblique lines of certain fixed angles are relatively simple to draw using the control words listed in Table 1.**

Table 1.

| vector (Fig. 11) | control word BIN. 7 6 5 4 3 2 1 0 | HEX. | DEC. |
|---|---|---|---|
| 1 | x x x x 1 0 0 0 | 0 8 | 0 8 |
| 1A | x x x x 1 1 0 0 | 0 C | 1 2 |
| 2 | x x 1 0 0 0 0 0 | 2 0 | 3 2 |
| 3 | x x 0 0 0 0 0 0 | 0 0 | 0 0 |
| 3A | x x 1 0 0 1 0 0 | 2 4 | 3 6 |
| 4 | x x 0 0 0 1 0 0 | 0 4 | 0 4 |
| 5 | x x 0 0 0 x x 1 | 0 1 | 0 1 |
| 5A | x x 1 0 0 x x 1 | 2 1 | 3 3 |
| 6 | x x 0 0 0 1 1 0 | 0 6 | 0 6 |
| 7 | x x 0 0 0 0 1 0 | 0 2 | 0 2 |
| 7 | x x 1 0 0 1 1 0 | 2 6 | 3 8 |
| 8 | x x 1 0 0 0 1 0 | 2 2 | 3 4 |
| 9 | x x x x 1 0 1 0 | 0 A | 1 0 |
| 9A | x x x x 1 1 1 0 | 0 E | 1 4 |
| 10 | x x 1 1 0 0 1 0 | 3 2 | 5 0 |
| 11 | x x 0 1 0 0 1 0 | 1 2 | 1 8 |
| 11A | x x 1 1 0 1 1 0 | 3 6 | 5 4 |
| 12 | x x 0 1 0 1 1 0 | 1 6 | 2 2 |
| 13 | x x 0 1 0 x x 1 | 1 1 | 1 7 |
| 13A | x x 1 1 0 x x 1 | 3 1 | 4 9 |
| 14 | x x 0 1 0 1 0 0 | 1 4 | 2 0 |
| 15 | x x 0 1 0 0 0 0 | 1 0 | 1 6 |
| 15A | x x 1 1 0 1 0 0 | 3 4 | 5 2 |
| 16 | x x 1 1 0 0 0 0 | 3 0 | 4 8 |
| pen selection | | | |
| pen 1 | 0 0 x x 1 x x 1 | 0 9 | 0 9 |
| pen 2 | 0 1 x x 1 x x 1 | 4 9 | 7 3 |
| pen 3 | 1 0 x x 1 x x 1 | 8 9 | 1 3 7 |
| lift all pens | 1 1 x x 1 x x 1 | C 9 | 2 0 1 |

x = don't care;
assumed logic 0 here

The flowchart of Fig. 10 shows that the control word is first sent to the output port that drives the plotter interface board. Full/half-step operation and direction of travel are set, and the clock input is programmed logic low. Next, bits Ø and 3 are examined to determine which motor is to perform a step. A 16-bit counter set up for the relevant motor is updated to keep track of the instantaneous coordinate. Direction of travel and full/half-step operation is taken into account as the counter is decremented or incremented. Bits Ø and 3 are made logic high, and the resultant control word is once again written to the output port. The selected motor(s) will thereupon perform one (full or half) step.

The two most significant bits control pen selection. In most cases, it will not be desired to perform a step while a pen is being selected, requiring bits Ø and 3 to be made logic high. Bit levels are frequently examined in the course of the elementary routine. The Type Z80 microprocessor offers special bit checking instructions. These can be simulated by other processors by, for example, logic ANDing of the control word with a mask byte in which the bit to be examined is logic high. The result of the check can then be read from the status of the zero-flag.

## Straight lines and pen selection

A small addition to the elementary routine makes it possible to draw straight lines at certain fixed slant angles. To begin with, the command word is set up, taking the bits for pen selection into account. The desired line length can be

related to a specific X or Y coordinate. Each step is followed by a check for arrival at the end position. When this has not yet been reached, the next step is performed after a short delay. The delay time can be generated with the aid of a simple software loop, or a timer as available in, for instance, the 6522-VIA or Z80-CTC. A hardware timer has the advantage of making the final step rate, within limits, independent of the program routine that is to be executed between two steps. It is the task of the programmer to ensure that the motors operate smoothly in both the full and the half-step mode. Motor control can be enhanced by programming equal acceleration and deceleration rates for both motors when these are being stopped and started. This reduces the risk of one motor lagging because it misses out on a few steps, and in addition keeps longitudinal vibration of the pen carriage to a minimum (this effect is caused by inertia in combination with elasticity of the string).

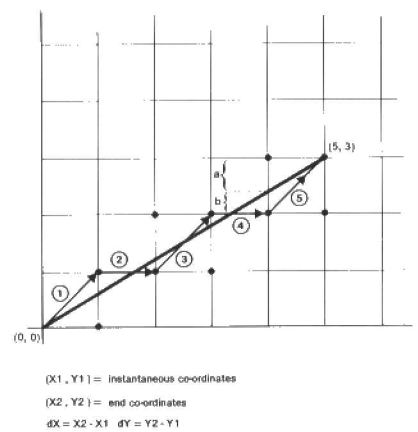
The wind-rose shown in Fig. 11 is drawn by actuating one or both motors, in combination with direction of travel and full/half-step operation. The number of full or half steps is always constant. Reverse the polarity of one stator when a motor revolves in the wrong direction. Table 1 may be examined to see how the various control words for drawing the wind-rose were built from individual command bits.
Bits 6 and 7 allow four logic combinations: three for putting the invidual pens on paper, and one (combination $11_2$) for lifting all three pens simultaneously. Pen-down commands are preceded by a small, fixed, displacement in the X direction (offset, 58 or 116 steps) to compensate the distance between the pens in the carriage.

## Random lines: Bresenham's algorithm

The drawing of oblique lines under slant angles other than the fixed ones discussed above is relatively complex. In most graphics applications, the working area is considered a system of coordinate axes. In this, a plotter should be able to draw a straight line between two random coordinates. In practice, however, the line drawn by the plotter will deviate from the desired, ideal, line owing to the limited number of discrete pen positions. Bresenham's line algorithm allows close approximation of the ideal line between random points in the coordinate system.

The drawing and Table in Fig. 12 illustrate the theory behind Bresenham's line algorithm. It is assumed that a line is to be drawn from starting point X1,Y1 — set at coordinates 0,0 for convenience's sake — and destination X2,Y2 at coordinate 5,3. Assuming the slant angle of the line to be smaller than 45° (Y2≦X2), the line can be drawn by actuating the X motor one step per increment, or the X and Y motor simultaneously. The choice between these options is determined by the difference between *a* and *b*. When *a* is greater than *b*, only the X motor is actuated, else the X and Y motor simultaneously. In essence, the procedure entails measuring the

12




| step | steps | error | decision | movement |
|---|---|---|---|---|
| 1 | 8 | 1 | error > 0 | 2 |
| 2 | 6 | −3 | error <= 0 | 1 |
| 3 | 5 | 3 | error > 0 | 2 |
| 4 | 3 | −1 | error <= 0 | 1 |
| 5 | 2 | 5 | error > 0 | 2 |
| 5a | 0 | — | return | — |

**Fig. 12. Bresenham's line algorithm. The ideal line is shown in bold print, the dots in the raster form the discrete positions that can be reached by the pen. The choice between stepping in the X or Y direction, or stepping obliquely (X and Y simultaneously) is made after calculating the difference between *a* and *b*.**

13

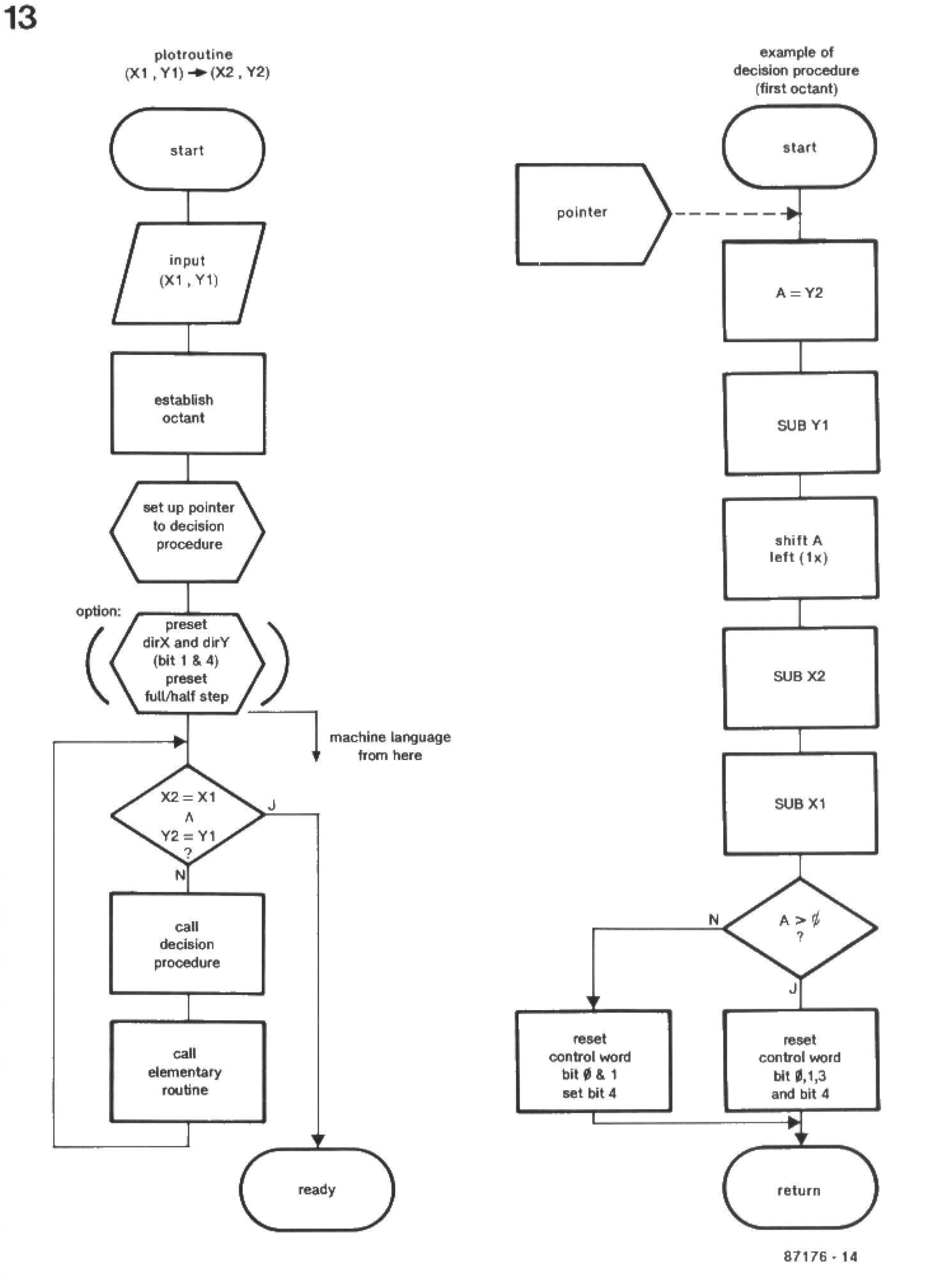



**Fig. 13. Suggested flow chart for drawing lines to Bresenham's algorithm. The right-hand sequence is an example of one of the eight decision routines listed in Table 2.**

angle of the line that can be drawn between the instantaneous and destination coordinates. When this angle is greater than 22°30' (2dY−dX>0), the next discrete position, X+1,Y+1, is stepped to at an angle of 45°. Otherwise, only the X motor performs a step.

The above algorithm is attractive because it allows simple calculations to be used for the decision procedure. Displacements dX and dY are deduced by subtraction, while multiplication by two is effected at machine code level by a single shift-left operation in the accumulator.

The same algorithm can be used for lines of angles between 45° and 90°, provided X and Y are exchanged. Lines in the remaining three quadrants are also fairly simple to draw to the above method. It is necessary, however, to determine beforehand in which octant (half quadrant) the destination coordinate will be with respect to the start-coordinate.

The flow diagram of Fig. 13 shows how lines between random coordinates can be drawn using Bresenham's algorithm. A routine is included to find out in which octant the destination coordinate is going to be with respect to the start-coordinate. Depending on the result, a pointer is preset to point to one of eight decision routines listed in Table 2a. In these, the control word is set up to define which motor (or motors) is to perform a step in a certain direction.

The actual stepping is done by calling the elementary routine. After each step, the instantaneous coordinates are compared to the destination coordinates (X2,Y2).

## Algorithm for octant one

Bresenham's line algorithm derives step information from the distance to be covered in the X and Y direction (dX and dY respectively). The algorithm for the first octant (angle between 0 and 45°) is shown in Table 3. First, dX and dY are calculated to obtain the initial value of decision variable "error", which must be corrected (updated) after each step. Depending on the direction of travel, "error" is corrected with d-error1 (after movement 1) or d-error2 (after movement 2). Variable "steps" holds the number of steps to be performed in the X and Y direction, and is used for stopping the plot routine in time. The actual plotting is done in a WHILE-DO loop. Depending on the value of "error", steps are straight (X or Y) or oblique (X and Y). Variable "steps" is decreased by one or two in accordance with the movement performed (remember that one oblique step is one step in the X direction and one in the Y direction, i.e. two steps in all).

The Table in Fig. 12 and the flowchart in Fig. 13 illustrate the operation of the algorithm with the aid of some variables. As already stated, the routine is only valid for the first octant. It is, however, fairly simple to modify for drawing lines in other octants. Depending on the octant in which the line is drawn, it will be necessary to:

- use the absolute value of dX and/or dY;
- swap dX and dY;
- adapt the two elementary movements.

Table 2a provides an overview of the above functions for each of the eight octants. The drawing of a line between two points in an arbitrary octant requires an extended version of the line routine. The flow diagram of this is shown in Fig. 14. The first part of the program (up to ATTENTION) is, in fact, a programmed version of Table 2a. This part of the routine ensures that the actual plot routine (the loop at the end) draws a line in the correct direction. The calculation of "error" is scattered over several branches, but is still in accordance with Table 2a when the decision routine is called.

The listing in Table 4 is a Pascal procedure written after the flow-chart of Fig. 14. It should be noted that the program is intended to draw lines on a computer screen, so that instantaneous coordinates X and Y are read and updated for use as end criterions. Variables

**Table 2a**

| octant | Δa | Δb | movement 1 | | movement 2 | |
|---|---|---|---|---|---|---|
| 0 . . . 45° | +dX | +dY | inc.X | — | inc.X | inc.Y |
| 45 . . . 90° | +dY | +dX | — | inc.Y | inc.X | inc.Y |
| 90 . . . 135° | +dY | −dX | — | inc.Y | dec.X | inc.Y |
| 135 . . . 180° | −dX | +dY | dec.X | — | dec.X | inc.Y |
| 180 . . . 225° | −dX | −dY | dec.X | — | dec.X | dec.Y |
| 225 . . . 270° | −dY | −dX | — | dec.Y | dec.X | dec.Y |
| 270 . . . 315° | −dY | +dX | — | dec.Y | inc.X | dec.Y |
| 315 . . . 360° | +dX | −dY | inc.X | — | inc.X | dec.Y |

dX = X2 − X1 X1, Y1 = start coordinates
dY = Y2 − Y1 X2, Y2 = destination coordinates
ERROR = 2 · Δb − Δa initial error
dERROR1 = 2 · Δb error change after movement 1
dERROR2 = 2 · Δb − 2 · Δa error change after movement 2

**Table 2b.**

| | control word |
|---|---|
| inc. x | x x x x x x 0 0 |
| dec. x | x x x x x x 1 0 |
| inc. y | x x x 0 0 x x x |
| dec. y | x x x 1 0 x x x |

**Table 3.**

```
dX = X2 - X1
dY = Y2 - Y1
error = 2dY - dX
derror1 = 2dY
derror2 = 2dY - 2dX
steps = dX + dY

WHILE steps > 0 DO
  IF error <= 0 THEN
                 step X
                 error = error + derror1
                 steps = steps - 1
               ELSE
                 step XY
                 error = error + derror2
                 steps = steps - 2
               ENDIF
ENDWHILE
```

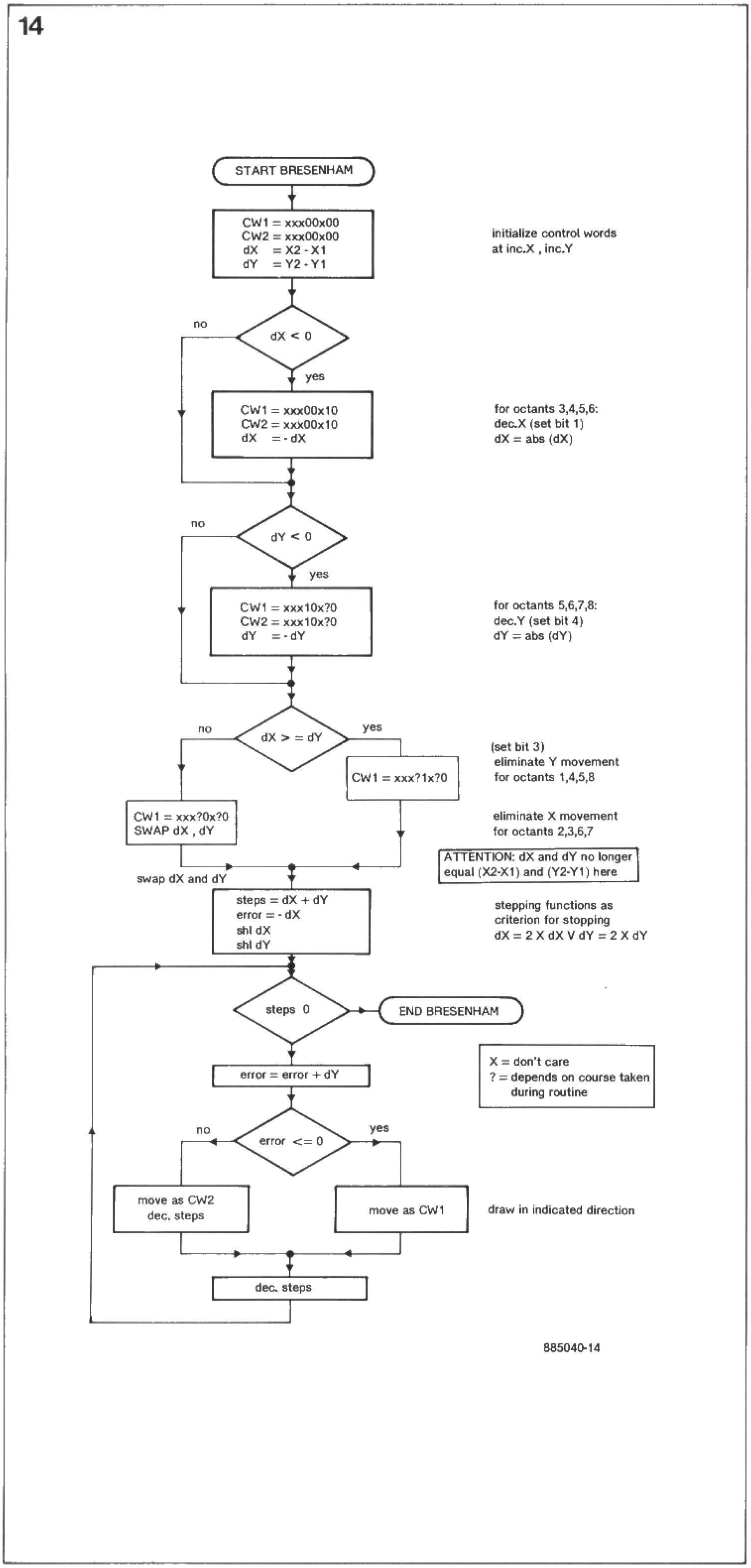



**Fig. 14. Flow diagram of the extended line drawing routine.**

STEP1 and STEP2 correspond to control word 1, and variables STEP3 and STEP4 to control word 2 in the flow diagram.

## Circles and ellipsoids

The plotter will have to draw circles frequently. A set of coordinates of a circle can be computed with the aid of two tables: one holds data of one period of a sine function, the other data of one period of a cosine function. Table entries are rounded off to the nearest integer. The sine table then holds X coordinates, the cosine table Y coordinates. The amplitudes form the radius in the X and Y direction. Equal amplitudes result in a circle, unequal amplitudes in an ellipsoid whose major axis runs in parallel with the X or Y axis. Ellipsoids which are oblique with respect to the X or Y axis are obtained by mutual shifting of the tables. This effectively creates phase shift variation.
Calculation of coordinates lays a rather heavy claim on processor time, and is, therefore, done beforehand. The result, in the form of two tables, is stored in memory. The circle can then be drawn by having the plotter step from point to point using the Bresenham algorithm.

## Extending the control program

The previously discussed elementary routine and general algorithms should enable programmers to develop a suitable control program for their computer. The bulk of the plotter control program may be written in a higher programming language, but there is no way to go round machine code for time critical routines. The final program should enable drawing

- lines between arbitrarily chosen coordinates (absolute function);
- lines between the current pen position and a coordinate defined with respect to that position (relative function);
- standard figures such as circles, squares, etc.;
- characters (letters, symbols and numbers).

Each character should have a corresponding set of relative coordinates, which can be multiplied by a fixed factor for enlarging or reducing character size.

*TW*

```
PROCEDURE BRESENHAM (X1,Y1,X2,Y2): WORD; ATTRIBUTE: CHAR; PAGE: BOOLEAN);

VAR X, Y, dX, dY, ERROR, STEP1, STEP2, STEP3, STEP4: WORD;

BEGIN
  dX := X2 - X1;
  dY := Y2 - Y1;
  STEP1 := 1; {initialize all steps at +1}
  STEP2 := 1;
  STEP3 := 1;
  STEP4 := 1;
  IF dX < 0 THEN BEGIN {initialize for octants 3, 4, 5, 6}
                   STEP1 := -1; {step backwards in X direction}
                   STEP3 := -1;
                   dX := -dX     {dX := ABS (dX)}
                 END
  IF dY < 0 THEN BEGIN {initialize for octants 5, 6, 7, 8}
                   STEP2 := -1; {step backwards in Y direction}
                   STEP4 := -1;
                   dY := -dY     {dY := ABS (dY)}
                 END
  IF dX >= dY THEN {eliminate Y direction in movement1 for octants
                    1, 4, 5, 8, and initialize decision variables.}
                   STEP2 := 0;
              ELSE {eliminate X direction in movement1 for octants
                    2, 3, 6, 7, and initialize decision variables.}
                   BEGIN
                     STEP1 := 0;
                     {dX and dY must be swapped.
                      ERROR serves as an auxiliary variable}
                     ERROR := dX; dX := dY; dY := ERROR;
                   END;
  {start plotting algorithm}
  X := X1; {make instantaneous and start coordinates equal}
  Y := Y1;
  ERROR := -dX;
  dX := 2 * dX; {these two lines prevent}
  dY := 2 * dY; {multiplications in the loop}
  HPLOT (X,Y,ATTRIBUTE,PAGE); {plot first pixel on screen}
  WHILE (X<>X2) OR (Y<>Y2) DO
  BEGIN
    ERROR := ERROR + dY;
    IF ERROR <= 0 THEN BEGIN {movement 1}
                         X := X + STEP1;
                         Y := Y + STEP2;
                       END
                  ELSE BEGIN {movement 2}
                         X := X + STEP3;
                         Y := Y + STEP4;
                         ERROR := ERROR - dX;
                       END;
    HPLOT (X,Y,ATTRIBUTE,PAGE) {plot pixel X,Y on screen}
  END
END;
```

Computer user groups and individual programmers are invited to write universally applicable software drivers for the plotter described. Publication in this magazine can be arranged in cooperation with the editor and a technical assessment committee. We are particularly interested in programs to the Hewlett Packard Graphics Language (HPGL) standard for the following computers: Acorn Archimedes, Acorn Electron, Amstrad CPC464, Atari ST, BBC B, Commodore Amiga, *Elektor Electronics* BASIC computer, IBM PC XT/AT and compatibles (Amstrad 1512/1640), MSX-2, Sinclair Spectrum and Quantum Leap.

Writers who have submitted programmes found suitable for publication are offered a publication fee and a year's subscription to this magazine. The closing date for sending in suggested programs is 1 December 1988.

# CORRECTIONS

## *Multi-function frequency meter*

**December 1987, p. 46 ff**

The polarization of diodes D7, D8 and D9 is shown incorrect on the component overlay printed on ready-made PCB Type 87286-A supplied by the Readers Services. Figure 3 on page 48 however is correct.

IC2 should be a Type 74HCU04, 74HC14 or 74HCT14, not a 74HCT04 or 74HC04 as stated in the parts list and the circuit diagram of Fig. 1. The Type 74HC14 or 74HCT14 is preferred for measurements below 1 kHz. It should ne noted that the measuring inputs represent a relatively low impedance (330 Ω). Removing R2 and R3 increases the input impedance to more than 1 MΩ, but results in reduced sensitivity.

## *Infra-red headphones*

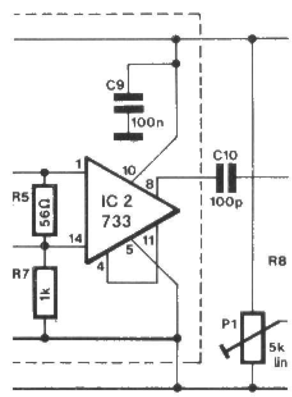
**February 1988, p. 65**

The parts list of the receiver should be amended as follows:
C6;C7=180p.

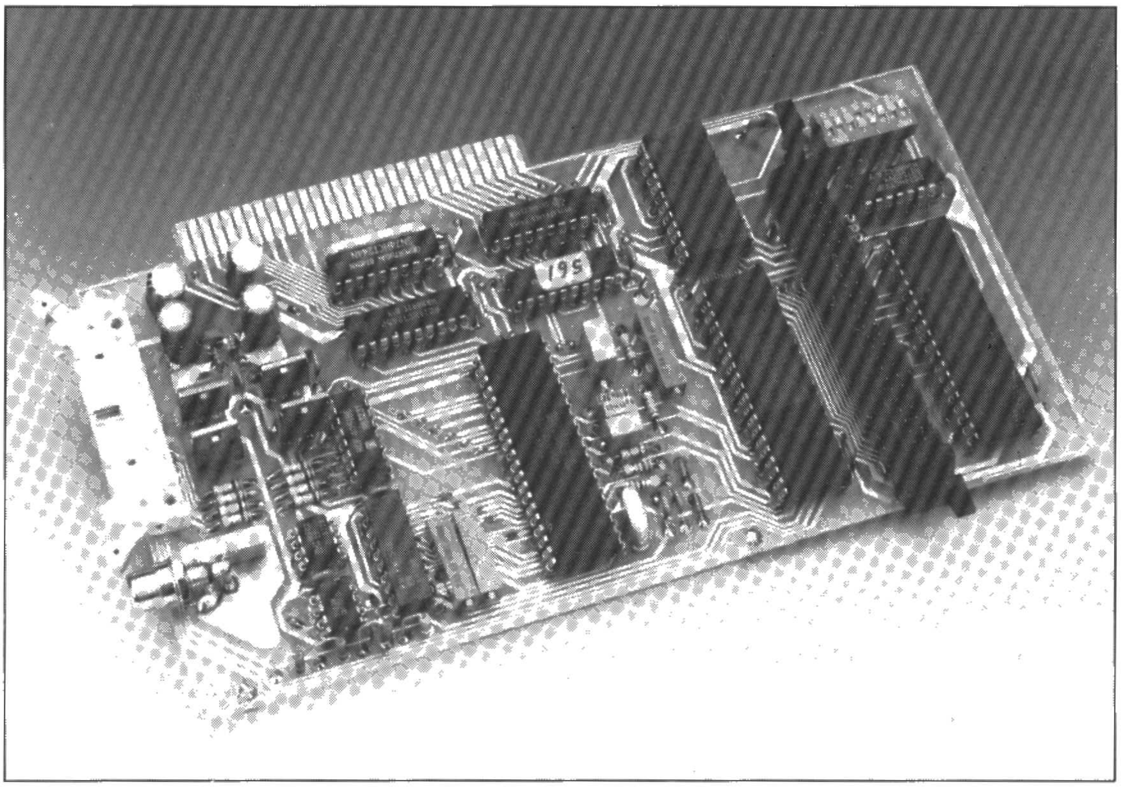
## *Prescaler for multi-function frequency meter*

**February 1988, p. 51.**

The circuit diagram of Fig. 4 should be corrected as shown opposite. The relevant PC board is all right.



# I/O EXTENSION CARD FOR IBM PCs AND COMPATIBLES



**For PC users bothered by the restrictions of the single parallel and serial I/O port on the standard machine we have developed an extension card that provides just about everything when it comes to using the computer for advanced control and instrumentation purposes.**

**I/O power for Big Blue!**

(Part 1)

Critized by some for its slowness, poor graphics facilities, size and weight, but hailed by many more as a strong unifying force in the traditionally wildly diversified "computer scene", the IBM Personal Computer (PC) has become the *de facto* standard for advanced home computing. Whatever the pros and cons, sales of PCs and inexpensive compatibles (*clones*) of far Eastern origin have been boosted by the massive amount of excellent software that may be copied freely, or is available at a nominal charge. For professional applications, there are software packages for virtually all tasks in a modern office environment, and an increasing number of PCs is also seen on the workfloor in many factories and other industrial sites. Currently, no computer manufacturer would dare bring out a machine that is not, to some extent, "MSDOS and/or IBM compatible".

Connecting a mouse the serial port, COM1:, and a printer to the parallel port, LPT1:, exhausts the I/O facilities of the standard PC-XT. The plug-in card described here is ideal for overcoming this serious limitation — see the main technical features in the Table below. The D-A and A-D conversion functions performed by the extension board, and the versatile counters/timers, should be of particular interest for process control applications where high accuracy is required.

**I/O EXTENSION FOR IBM PC**
**Technical characteristics:**

- 32 I/O lines
- 3 programmable counters/timers
- One 12-bit D-A converter
- One 12-bit A-D converter
- 8 multiplexed analogue inputs
- Fully buffered bus

The block diagram of Fig. 1 shows the general layout of the I/O extension. The configuration adopted is fairly standard for computer extension cards, and should require little explanation. The computer and the card communicate via the bus buffer. All data, address and control lines are buffered to prevent damage to the computer's internal circuitry. The address decoder translates the address and control signals from the computer into block selection signals for the I/O circuits. The card address range can be selected by means of a jumper. Both available ranges ($30x_H$ and $31x_H$) fall within an address area reserved by IBM for experimental extension cards in the PC. The I/O extension card can be safely mapped there because the relevant address area will almost certainly not be shared with other cards.

The main building blocks on the I/O card are a Programmable Interval Timer (PIT), two Programmable Peripheral Interfaces (PPIs), a 12-bit A-D converter

(ADC) and a 12-bit D-A converter (DAC). The input of the ADC is driven by an 8-channel analogue multiplexer, so that the card has a total of eight analogue inputs.

## PIT 8253

The internal organization of this well-known chip from Intel is shown in Fig. 2. Counters 0, 1 and 2 are identical: each is a presettable 16-bit down-counter which can be programmed to operate in binary or BCD mode. The use of inputs clc (clock) and gate, and the chip output, can be defined by software. The three counters operate completely independently of one another, and are individually programmable. Counter contents as well as intermediary states can be read without having to block the counter input.

Timer settings are defined by four bytes written into the control word register. This occupies only one address, so that two bits, SCØ and SC1, in the control word are reserved for addressing the relevant counter. Available counter modes and associated bit functions are shown in Table 1a.

Reading from and writing to the counters is simple. There is no fixed addressing order, provided the information in the read/load bits of the control word is observed. Read and write operations in a particular counter need not always be preceded by a control word, since this remains valid for each individual counter until it is overwritten. Table 1a also lists the six programmable counter modes, which will be discussed below with reference to the timing diagrams of Fig. 3. The mode descriptions are summaries of the relevant sections in Ref. [1], which may be consulted for further details.

### Mode 0: interrupt on terminal count

The output is low after this mode has been selected. Counting down commences after loading the count register. The output goes logic high when state nought (*terminal count*) is reached, and remains high until the selected count register is reloaded with a mode control word, or a new count value is loaded. Note that counting continues after terminal count has been reached. Hence, reading of the counter contents gives apparently random results.

### Mode 1: programmable one-shot

The output of the 8253 goes low on the count following the positive edge of the signal on the gate input. The output remains low while the counter is decremented, and goes high when state nought is reached.

The counter latches the new preset value on the positive edge of the gate signal, so that it can function as a retriggerable monostable multivibrator (one-shot).

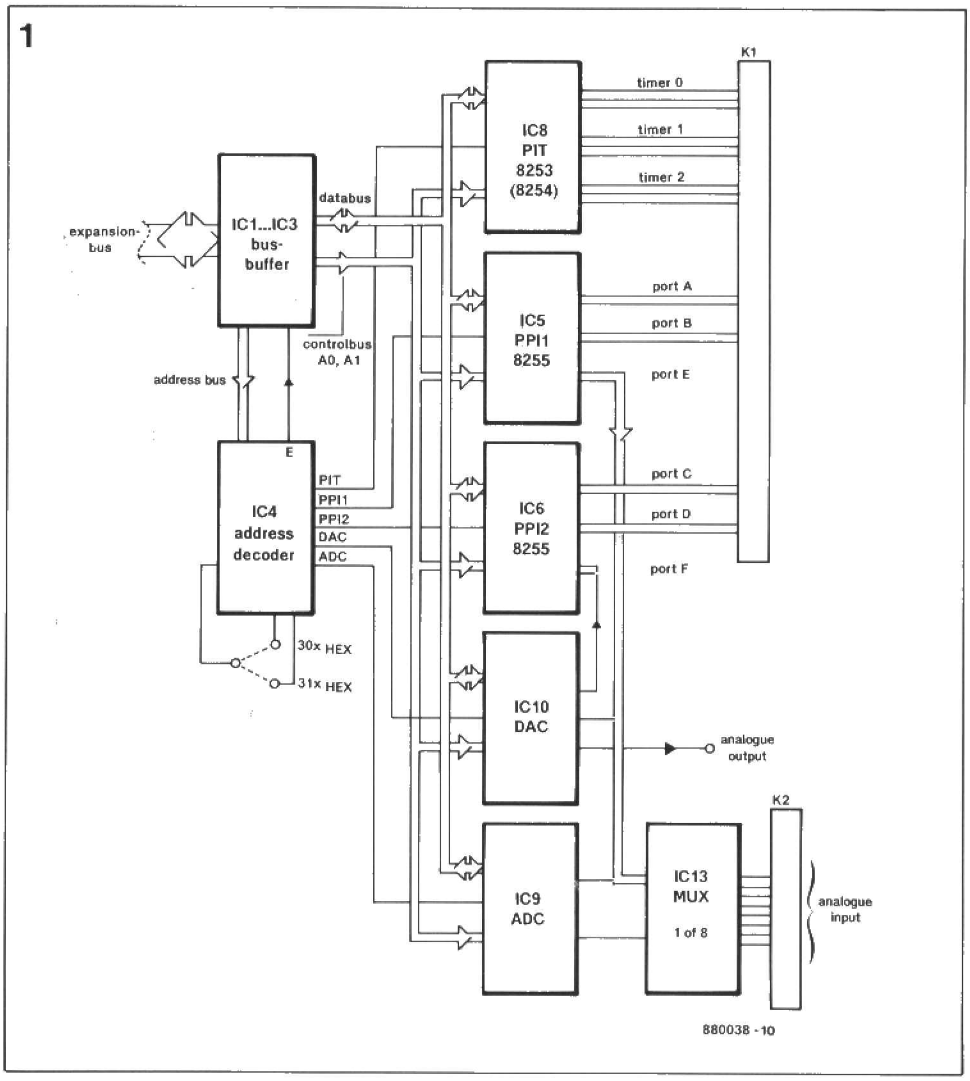



**Fig. 1. Block diagram of the input/output extension card for IBM PCs and compatibles.**

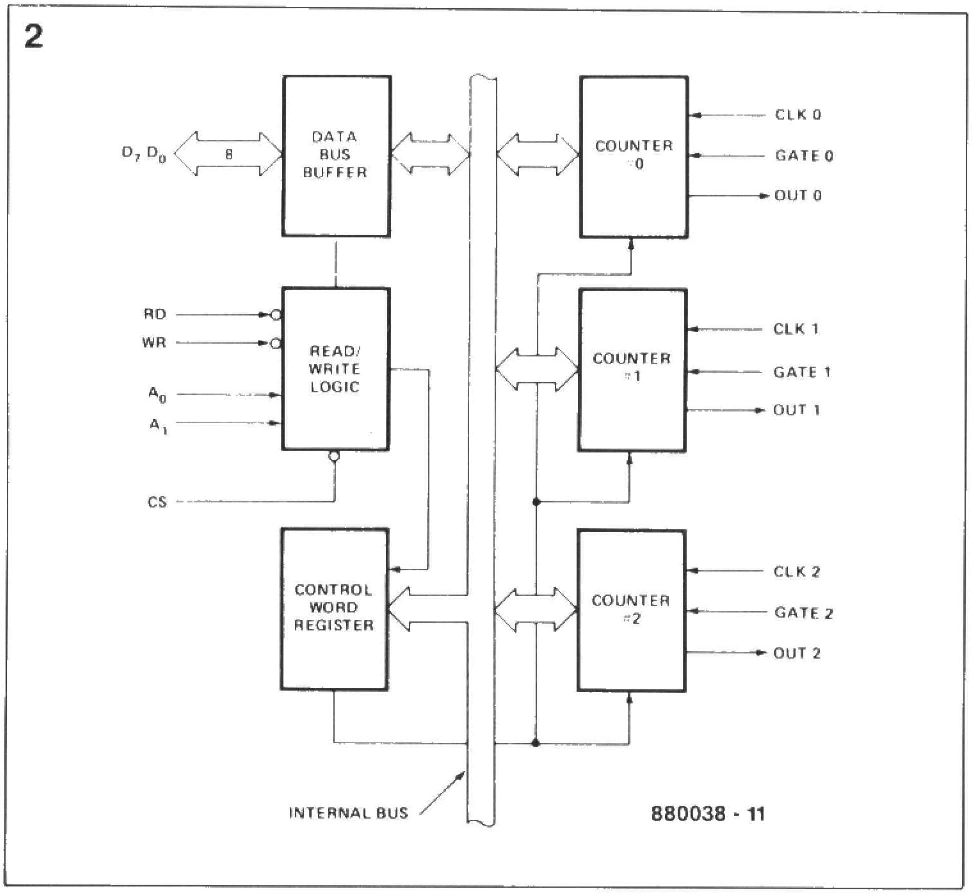



**Fig. 2. Internal structure of the Type 8253 programmable counter/timer (*courtesy Intel*).**

**Mode 2: rate generator**
In this mode, the count register functions as a divide-by-*n* counter. The output goes low for one period of the input clock when the counter reaches state nought. The period of the output signal is, therefore, the preset count multiplied by the period of the clock signal. The output is not affected by the loading of a new count value until the end of the current period.
In this mode, the gate input functions as a counter enable/disable switch, and can, therefore, be used to synchronize the counter. The counter output is high when the gate input is made low. When the gate input is high, the counter register is loaded, and decrementing begins. Synchronizing can also be done in software, since the output remains high between loading the control word that selects the rate generator mode, and loading of the count register.

**Mode 3: square wave rate generator**
This mode is similar to mode 2 with the exception of the output toggling when half the count period has lapsed. If the loaded count is an even number, the output duty factor will be 0.5. For odd-numbered counts, the "high" time of the output signal will be one clock period longer than the "low" time.

**Mode 4: software triggered strobe**
Setting this mode causes the output to go high. Decrementing of the count value starts after this has been loaded. On reaching state nought, the output goes low for one input clock period, then will revert to the high state. If the counter is reloaded between output pulses, counting will continue from the new value. Counting down will be inhibited when the gate input is held low.

**Mode 5: hardware triggered strobe**
In this mode, which is similar to mode 4, the counter will start decrementing the loaded count on the rising edge of the gate input. The output will go low for one clock period when state nought is reached. While counting down, the counter is retriggerable by means of the rising edge of the gate signal.

The function of the gate signal in the above modes of the 8353 is summarized in Table 1b.

Reading of the count register contents is basically simple. To prevent clock pulses interfering with read operation, the counter must first be stopped by programming of the gate input, or by blocking the clock signal. Alternatively, the counter can be frozen by the processor sending a control word of the following bit-configuration:

SC1 SCØ Ø Ø x x x x

In this, SCØ and SC1 address the relevant count register, while the two logic low bits freeze the contents. The logic level of bits designated x is irrelevant.
Finally, an important technical specification of the 8253: the maximum clock frequency for this device is 2.6 MHz. Depending on the version, a Type 8254 may be used instead of the 8253 for clock frequencies up to 5, 8 or 10 MHz.

## PPI 8255

Like the 8253, this versatile Programmable Peripheral Interface is among the best known and most widely used ICs in Intel's range of peripheral support chips that was initially designed for operation

Table 1a.

| $D_7$ | $D_6$ | $D_5$ | $D_4$ | $D_3$ | $D_2$ | $D_1$ | $D_0$ | |
|---|---|---|---|---|---|---|---|---|
| SC1 | SC0 | RL1 | RL0 | M2 | M1 | M0 | BCD | **Control Word Format** |

| BCD | |
|---|---|
| 0 | Binary Counter 16 bits |
| 1 | Binary Coded Decimal (BCD) Counter (4 Decades) |

| M2 | M1 | M0 | |
|---|---|---|---|
| 0 | 0 | 0 | Mode 0 |
| 0 | 0 | 1 | Mode 1 |
| X | 1 | 0 | Mode 2 |
| X | 1 | 1 | Mode 3 |
| 1 | 0 | 0 | Mode 4 |
| 1 | 0 | 1 | Mode 5 |

| RL1 | RL0 | |
|---|---|---|
| 0 | 0 | Counter Latching operation |
| 1 | 0 | Read/Load most significant byte only. |
| 0 | 1 | Read/Load least significant byte only. |
| 1 | 1 | Read/load least significant byte first, then most significant byte. |

| SC1 | SC0 | |
|---|---|---|
| 0 | 0 | Select Counter 0 |
| 0 | 1 | Select Counter 1 |
| 1 | 0 | Select Counter 2 |
| 1 | 1 | Illegal |

Table 1b.

| Modes \ Signal Status | Low Or Going Low | Rising | High |
|---|---|---|---|
| 0 | Disables counting | -- | Enables counting |
| 1 | -- | 1) Initiates counting 2) Resets output after next clock | -- |
| 2 | 1) Disables counting 2) Sets output immediately high | 1) Reloads counter 2) Initiates counting | Enables counting |
| 3 | 1) Disables counting 2) Sets output immedately high | 1) Reloads counter 2) Initiates counting | Enables counting |
| 4 | Disables counting | -- | Enables counting |
| 5 | -- | Intiates counting | -- |

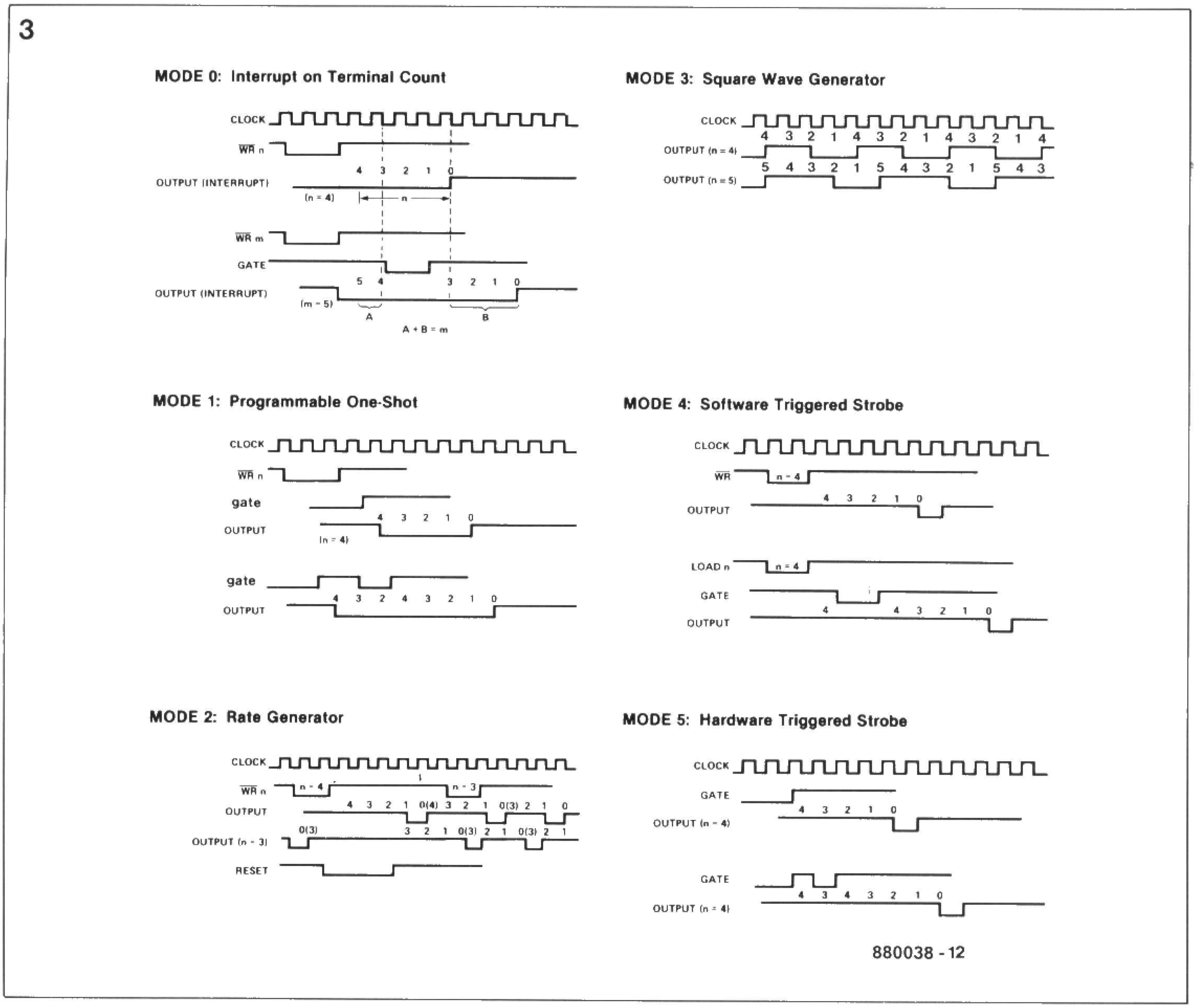



**Fig. 3. Timing diagrams illustrating the operation of the 8253 in the various modes available (*courtesy Intel*).**

in 8080 and 8085 based computer systems.

The internal structure of the 8255 is apparent from the block diagram of Fig. 4. The three 8-bit wide I/O ports are divided in two groups of one and a half port each. This perhaps slightly confusing configuration is explained by the handshake facilities offered by the IC, which can be programmed to operate in

**mode 0** for basic input/output;
**mode 1** for strobed input/output;
**mode 2** for bidirectional bus applications.

Conventionally, the PPI mode is selected by loading the appropriate control word. The resulting port configurations are shown in Fig. 5. The odd man out is Port C, which can be divided into two 4-bit ports that can be used for I/O, handshaking and/or interrupts, all in conjunction with Ports A and B. The IC is thus divided in two functional blocks of 12 I/O lines each. The functional division is easily recognized in the bit-

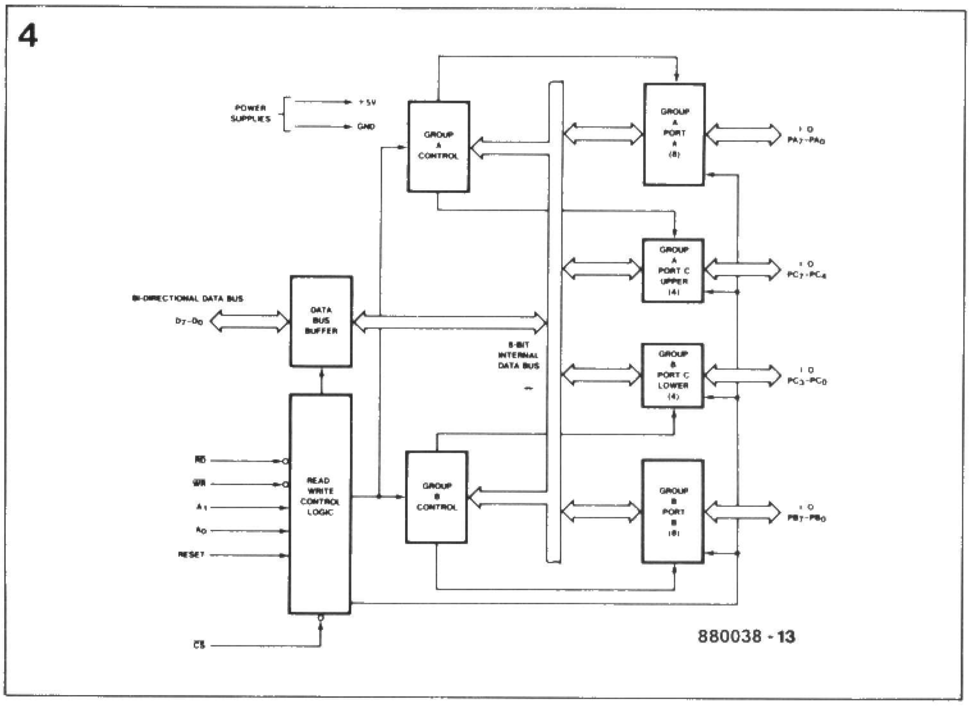


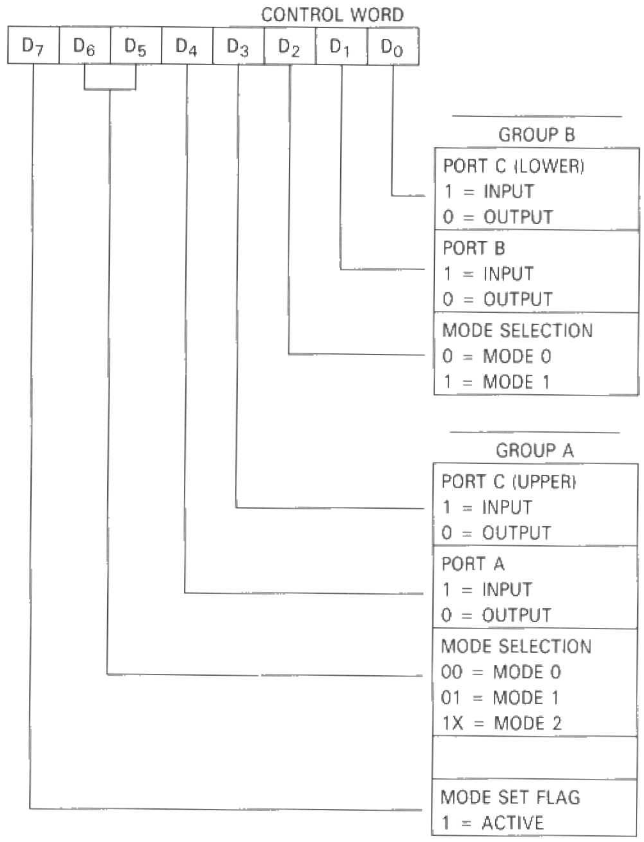

**Fig. 4. Internal organization of the Type 8255 programmable peripheral interface (*courtesy Intel*).**

configuration of the control word — see Table 2. Contrary to PIAs, PIOs and a good many other I/O ICs, the 8255 does not allow programming of individual bits as input or output.

Bit 7 in the mode selection word is always logic low. Mode 0 is the simplest configuration, since the processor can simply read from, or write to, the relevant register to perform input/output operations. When a Port is set to the output mode, it can also be read. The operation of the PPI in Modes 1 and 2, and with bit 7 in the control word programmed logic low, is, unfortunately, beyond the scope of this article. Programmers are, therefore, advised to consult the relevant data-sheets in Ref. [1].

The current that can be supplied by an output line of the 8255 is more than 1 mA at an output voltage of 1.5 V. This makes it possible to drive a darlington transistor direct. Outputs can easily sink 2.5 mA.

Table 2.




## Analogue-digital converter

The 12-bit ADC Type ICL7109 is really a 13-bit type since it provides a polarity bit in addition to the 12 data bits. The control of the ADC is detailed below in the section on the operation of the I/O extension card.

Table 3 shows that an over-range bit, OR, has been added to the 13 bits already available. The 14 bits are comprised in two bytes as shown in the Table. OR is logic high when the input voltage exceeds the maximum scale value, while POL is high when the input voltage is positive. The 13 databits provide the digital equivalent of the absolute value of the input voltage. Bits D6 and D7 in the MS byte are irrelevant, and should be ignored by the computer program.

Table 3.

| $D_7$ | $D_6$ | $D_5$ | $D_4$ | $D_3$ | $D_2$ | $D_1$ | $D_0$ | $D_7$ | $D_6$ | $D_5$ | $D_4$ | $D_3$ | $D_2$ | $D_1$ | $D_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| x | x | POL | OR | $B_{11}$ | $B_{10}$ | $B_9$ | $B_8$ | $B_7$ | $B_6$ | $B_5$ | $B_4$ | $B_3$ | $B_2$ | $B_1$ | $B_0$ |

## Digital-to-analogue converter

The Type PM-7548 from PMI does not have a thirteenth bit, so that its resolution is, strictly speaking, 1 bit lower than that of the counterpart ADC on the I/O extension card. Numbers applied to the PM-7548 are represented in the so-called *offset binary code*, which is obtained by adding the maximum negative value to the actual value. This means that, for instance, 0 corresponds to $-2048$ ($-2048+2048=0$), 2048 to actual value 0, and 4097 to actual value $+2047$. The code is simple to convert to a two's complement and vice versa by inverting the most significant bit.

5

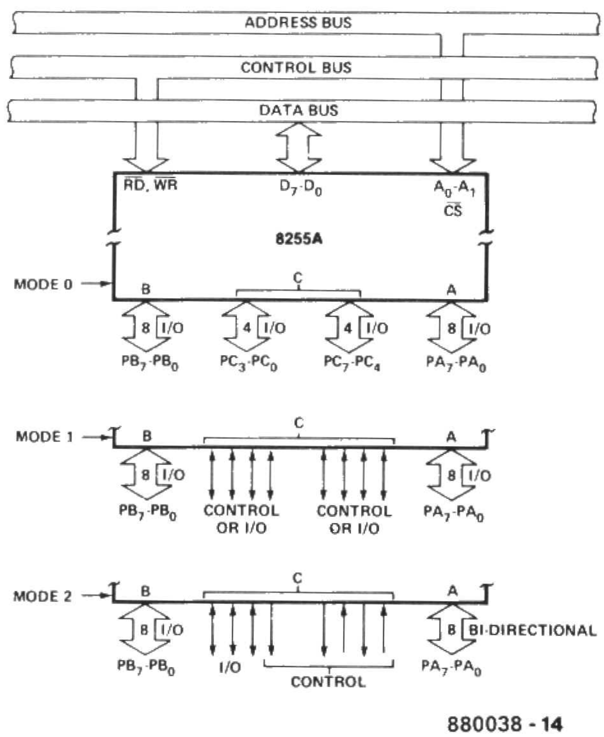



**Fig. 5. Function of the I/O lines in the various programmable modes.**

*To be continued next month.*

# HF OPERATION OF FLUORESCENT TUBES

**A circuit is described that enables HF control of fluorescent tubes. This not only increases the already high luminous efficacy of these lamps, but also enables them to be dimmed gradually.**

Although fluorescent tubes have a much higher luminous efficacy* (80-90 lm/W) than ordinary, vacuum light bulbs (about 15 lm/W), and have a much longer life expectancy, they are nowhere near as popular for use in the home. This unpopularity is caused by the 'cold' character of the light, the difficulty of controlling (dimming) the light, and the objectionable behaviour (flickering) immediately after switch-on. Although the present circuit cannot alter the character of the light (manufacturers are already producing much 'warmer' fluorescent tubes), it does obviate the other two undesirable aspects.

## Economy of HF control

High-frequency control units for fluorescent lamps have been available for some time, but so far these are mainly used in factories, office blocks, and other large buildings. The principal reason for their use there is that they provide a higher luminous efficacy. This comes about because the transformation of electrical into luminous power is more efficient at higher frequencies, and also because the losses in the control units are smaller at such frequencies (the choke of a domestic 40 W fluorescent lamp dissipates about 9 W). These advantages are, of course, not of such great importance for domestic lighting, because the resulting savings on the electricity bill are small. The main reason for adopting the present circuit in the home is seen primarily in the dimming facility.

## Conventional set-up

A fluorescent tube usually consists of a long glass tube T (see Fig. 1), which is internally coated with a fluorescent powder, although other shapes are now also on the market. The tube contains a small amount of argon together with a little mercury. At each end of the tube there is an electrode E that invariably consists of a coiled tungsten filament coated with a mixture of barium and strontium oxides. Each electrode has attached to it two small metal plates, one at each end of the filament. These plates act as anodes for withstanding bombardment by electrons during the half-cycles when the electrode is positive. During the other half-cycles, the adjacent hot filament acts as the cathode, emitting electrons.

Before the gas in a fluorescent tube can be ionized, certain conditions must be met by the control circuit, consisting of choke L and starter switch G. Before the gas is ionized, the resistance measured between the two electrodes is high.

Switch G, called a glow switch, is, strictly speaking, a small glow discharge lamp filled with a mixture of argon, helium, and hydrogen at low pressure. The contacts of the glow switch are normally open, but when the supply voltage is switched on, a glow discharge is started between the electrodes of the switch. The resulting heat is sufficient to bend the bimetallic strips until they make contact and close the circuit between electrodes EE of the tube. A fairly large current then flows through these electrodes, the value of which is determined by choke L. The current heats the electrodes, which, by thermal emission, results in a number of free electrons in the tube. These electrons are necessary for the onset of ionization (avalanche effect).

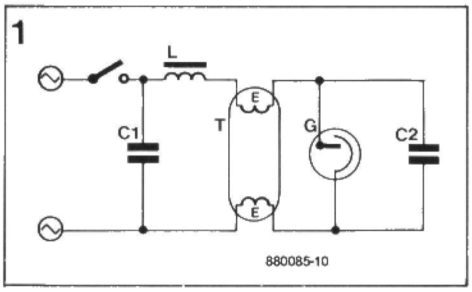



**Fig. 1. Circuit of conventional low-pressure fluorescent tube.**

Because the contacts of G are closed, the dissipation in this switch diminishes rapidly. This causes the bimetallic strips in G to cool and after a second or two the contact between these strips is broken. The consequent sudden reduction in current induces an e.m.f. of about 1000 V in L. The sum of this e.m.f. and the mains voltage is sufficient to ionize the argon in T. This reduces the resistance of the tube and the choke limits the current to a value specified by the manufacturer. The voltage drop across T is then of the order of 100 V, which is lower than the voltage required to ignite the glow switch.

The reason that fluorescent tubes flicker before they ignite properly is that the reduction in current caused by the bimetallic strips opening happens randomly with respect to the period of the mains voltage. If they open at the instant when the current through the choke is small, the induced e.m.f. may not be large enough to ionize the argon in T. In that case, the starting process repeats itself until ionization does take place.

The power factor of the circuit is raised from about 0.5 to 0.9 (lagging) by capacitor $C_1$.

Capacitor $C_2$ is an RF suppressor.

Most energy of this type of fluorescent lamp is radiated at a wavelength of 253.7 nm, which is in the ultra-violet region. The fluorescent coating of the tube absorbs this energy and converts it into visible radiation. Different coatings reradiate the absorbed energy at different wavelengths: zinc-beryllim silicate gives yellow to orange; cadmium borate and yttrium red; magnesium tungstate pale blue; and zinc silicate green. The use of appropriate mixtures of these powders make it possible to attain any desired colour.

## Dimming

Dimming of fluorescent tubes operating at the mains frequency is troublesome.

*The term 'luminous efficiency' would be incorrect, since that is the ratio of output power to input power when both are expressed in the same unit.

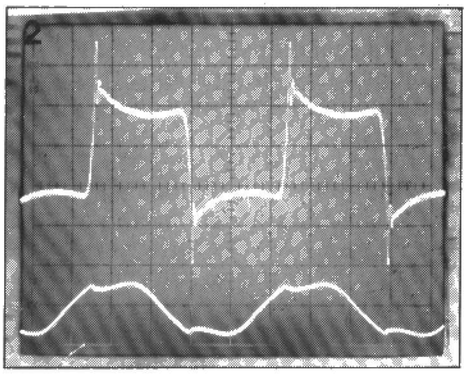


**Fig. 2. Waveforms of voltage and current in a conventional fluorescent tube.**

The reason for this may be seen in Fig. 2, which shows the voltage and current as functions of time. It is seen that after each and every zero crossing the voltage must rise substantially before the tube relights. Although the light output of all fluorescent tubes therefore fluctuates at twice the mains frequency, the visible effect of this is fortunately considerably reduced by the persistence of glow of the fluorescent coating.
If the tube is dimmed with the aid of a conventional triac circuit, the length of time that the current through the tube is zero becomes longer, and the risk of the tube being extinguished becomes greater. There are a number of ways of preventing this situation. The first is to maintain the high temperature of the electrodes with the aid of an external holding current. The second is to use a resistance strip along the tube as an aid to ignition. This strip is connected at one end to the electrode via a high-value resistor. At the other end it causes a kind of pre-ignition (the effective distance between the electrodes is reduced, which causes the fieldstrength to be locally much more intense). The third is to increase the frequency of the mains to a value where the period is small with respect to the recovery time of the ionized gas in the tube. The circuit described here uses this last method.

## Block schematic

The circuit is, in fact, an a.c.–a.c. converter. The mains voltage is first rectified (full wave) and smoothed. The resulting direct voltage of 300 V is then converted to a square-wave voltage with a frequency of 80 kHz (at start-up) or 30 kHz (normal operation). The fluorescent tube is part of a series LC circuit that is shunted by a capacitor. As long as the tube is not lit, it has a high resistance and does not load the circuit. At the relatively high start-up frequency, the reactance of the capacitor is relatively low. When a voltage is applied across the circuit, a current will flow that causes the electrodes of the tube to be heated. Just after switch-on, the frequency will decrease gradually. As soon as it approaches the resonant frequency of the circuit, the impedance of the circuit will drop rapidly, which will result in a much larger current through the electrodes. At the same time, the voltage across both L and C is increased greatly. Since the tube is in parallel with C, it will light readily. As soon as this happens, the tube resistance drops considerably and this will damp the LC circuit. The current through the electrodes will then become much smaller. The control circuit further reduces the frequency until it reaches a value of 30 kHz. The currents through the tube and capacitor will be small, because the ignition voltage across the lamp (and thus the p.d. across the capacitor) is relatively low and also because the reactance of the capacitor at 30 kHz is relatively large.
Dimming of the tube is effected by controlling the current through it. In contrast to conventional triacs, the present circuit is a real control loop. The current is measured with a current transformer and fed back to the control circuit. The latter circuit varies the duty cycle until the measured current has the same value as the set current. This arrangement enables dimming of the tube to near-extinction. Quenching it completely is not possible, because that would necessitate a new start cycle (with the consequent frequency swing). The current regulation also ensures that at start-up, when the lamp current is zero, the duty cycle of the output signal is automatically optimized. In this manner, the tube will always start smoothly, independent of the position of the dimmer control.

## Circuit description

In Fig. 6, fuse $F_1$ and chokes $L_1$ and $L_3$ are shunted by varistor $R_{25}$, which sup-

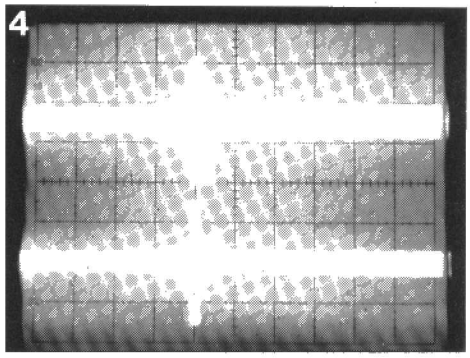


**Fig. 4. Electronic starting: the frequency swings from 80 kHz to 30 kHz. When it is about 50 kHz, the tube lights.**

presses spikes on the mains supply. The mains voltage is rectified in bridge $D_3$–$D_4$–$D_5$–$D_6$ and smoothed in $C_5$. The peak current through $C_5$ is limited by $R_{26}$. It should be borne in mind that switch-on may occur at any moment during the mains cycle: the peak charging currents that may occur should not be understimated. To keep the dissipation in $R_{26}$ low, an NTC type is used here. Immediately after switch-on, this heats up, which causes its resistance to drop from 50 ohms to about 2 ohms, effectively limiting the dissipation.
Capacitors $C_4$ and $C_6$ and diodes $D_1$, $D_2$, and $D_7$ form a pre-control for the supply voltage to the drive circuit. This voltage is stabilized at 12 V by $IC_4$. The maximum current that can be drawn from this supply is 30 mA (determined by $C_4$). The drive circuit draws about 20 mA.
The power stage consists of $T_1$ and $T_2$, which are connected as a half-bridge. The voltage at the junction of $T_1$ source and $T_2$ drain swings between 0 V and 300 V (= the rectified mains voltage). The d.c. component of this voltage is blocked by capacitors $C_2$ and $C_3$. One capacitor would have been sufficient, but two in series give some extra decoup-

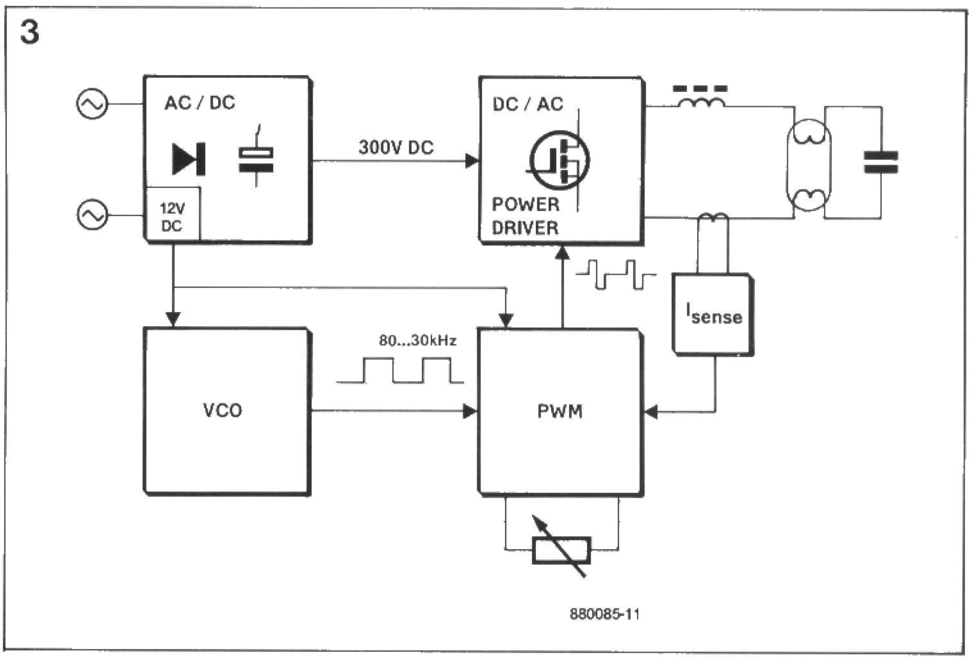



**Fig. 3. Block schematic of HF controller.**

ling of the high-voltage supply. As far as the a.c. through the lamp is concerned, the two capacitors are in parallel.

The power FETs contain parasitic free-wheeling diodes that are active during the dimming of the lamp. During dimming, both FETs are switched off for part of the period of the applied voltage. The voltage at the junction of $T_1$ source and $T_2$ drain, because of series circuit $L_1-C_1$, will swing several times between 0 V and 300 V during that time, which causes the free-wheeling diodes to conduct alternately (see Fig. 5b). A new period starts with $T_1$ being switched on. Now assume that $D_{17}$ is shunted, $D_{16}$ is not there, and that the free-wheeling diode in $T_2$ conducts just at the instant $T_1$ is switched on. During the recovery time of the free-wheeling diode in $T_2$ a short peak current will flow through both $T_1$ and $T_2$, which will affect the dissipation adversely. Since this problem is caused by the relatively long reverse-recovery-time of the internal free-wheeling diode in $T_2$ (typically of the order of 1.8 $\mu$s), it is obviated by connecting diode $D_{17}$ in series with $T_2$, because this prevents the parasitic diode from conducting. The series-connected diodes can then be shunted by a much faster free-wheeling diode, $D_{16}$ ($T_{rr}$=25 ns typically).

The series LC circuit is formed by $L_1$ and $C_1$. The circuit is damped by $R_{23}$ and $R_{24}$. Without these resistors, the damping of the circuit would be dependent solely on the resistance of the tube electrodes. Because this is very low, very large values of current and voltage might ensue before the tube lights. Resistor $R_{23}$ guarantees a given minimum series resistance in the circuit. The resistance of varistor $R_{24}$ will drop as soon as the voltage across $C_1$ exceeds a maximum value of about 1 kV. The clamping of the potential across $C_1$ will prevent too high an upswing of voltage and current in the circuit. As soon as the tube lights, its resistance will further damp the circuit. Since the final potential drop across the lamp is relatively low, additional dissipation in $R_{24}$ is prevented because the varistor has a high resistance at that voltage.

Since the operating frequency of 30 kHz is much higher than the conventional 50 Hz, the self-inductance and dimensions of choke $L_1$ can be accordingly smaller. Although it would be possible to limit the lamp current to a given value with the aid of the current regulating circuit, it is better done by the choke. The self-inductance is chosen so that at maximum duty cycle the lamp current does not exceed the value specified by the manufacturer of the tube.

## Control circuit

The control circuit has two tasks:

- the generation of a frequency that within about 2 seconds from switch-on swings from 70-80 kHz via the resonance frequency of 50 kHz to the normal operating frequency of 30 kHz.
- the controlling of the lamp current in accordance with a variable desired value to enable dimming of the lamp.

The current is controlled by varying the pulse width of the drive signal.

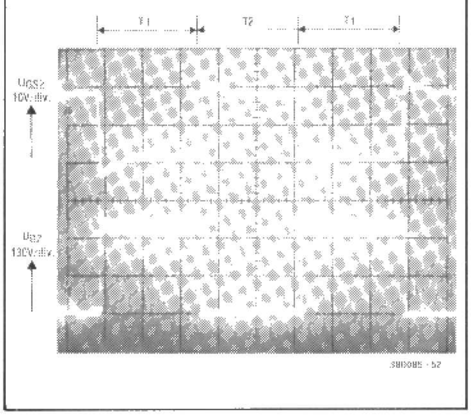



Fig. 5a. Gate signal (upper trace) and the voltage at the junction of $T_1$ source and $T_2$ drain at maximum duty cycle. The 'broad band' in the lower trace is caused by the 50 Hz ripple.

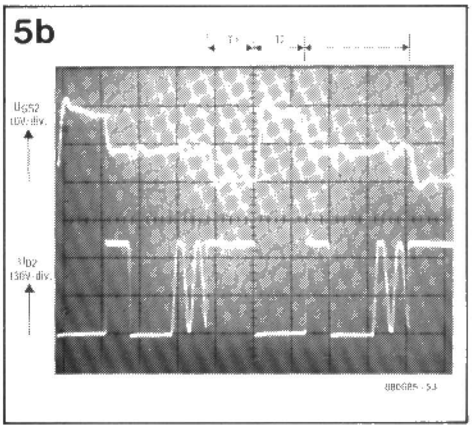



Fig. 5b. The same signals as in 5a, but with the tube dimmed. During the freewheeling period neither of the MOSFETs conducts, and the drain – source junction swings several times between 0 V and 300 V.

Frequency synthesis is provided by the VCO in $IC_1$, a Type 4046 CMOS PLL. The supply voltage is kept steady by zener $D_{15}$. Should the supply drop below 11 V, both $T_7$ and $T_8$ are switched off. The 4046 is then inhibited. When the input voltage is not lower than 11 V, $C_7$ is connected to the positive line via $T_7$. Since the capacitor at first has no charge, the VCO input will also tend to rise to 12 V, but is prevented by $D_{12}$ from exceeding 4.5 V. From this voltage, a signal at a frequency of about 70 to 80 kHz is generated. Capacitor $C_7$ is then charged via $R_{16}$, which causes a drop in the potential at the junction of $C_7$ and $R_{16}$. When this voltage drops below 4 V (the earlier mentioned 4.5 V less the drop across $D_{13}$), the VCO input is pulled down and the frequency of the output signal drops. The operating VCO input, and thus the operating frequency, is determined by potential divider $R_{17}-R_{16}$.

Multivibrators $MMV_1$ and $MMV_2$ provide the pulse width modulation. The VCO signal has a duty factor of 50% (square wave). $MMV_1$ is triggered at the leading edge of this signal. Immediately on termination of the mono period of $MMV_1$, the other multivibrator, which has an identical mono period, is triggered. The mono period of the multivibrators is variable because $C_{15}$ and $C_{16}$ are not charged via a fixed resistance, as is usual, but by a variable current source (strictly, current mirror): $T_4$ and $R_6$ and $T_3$ and $R_7$ respectively.

The magnitude of the current, and thus the mono period and duty cycle, is constantly adjusted, as required, by the current regulating circuit. The mono periods can not become longer than the half-periods of the VCO signal. Were one of the multivibrators likely to generate a longer period, this would be terminated prematurely by the reset input. In this manner, it is ensured that the maximum duty cycle of the circuit is exactly 50% as determined by the 50% duty factor of the VCO signal. This is, of course, essential to guarantee symmetrical control of the output stage.

The output stage is driven by a pulse transformer, $Tr_1$, which is contained in bridge $T_5-T_6-T_9-T_{10}$. Any d.c. components caused by small deviations of the mono periods are blocked by $C_{12}$. Such d.c. components would cause an unnecessarily large current in the low-ohmic primary of the pulse transformer, which might lead to saturation of the core of the transformer.

The MOSFETs are driven direct by the secondaries of $Tr_1$. It is, of course, imperative that these windings are connected in anti-phase to make sure that the MOSFETs cannot be switched on simultaneously. Resistors $R_2$ and $R_3$ serve to damp any oscillations caused by parasitic self-inductances. The zener diodes in the gate circuits limit the amplitude of the gate voltage.

To make current regulation possible, the lamp current is measured by a current transformer, $Tr_2$. A complication here is $C_1$, which is in parallel with the tube. This means that not only the current through the lamp, but also that through the capacitor, is measured. When the lamp is dimmed, and the current through it is, therefore, small, the current through the capacitor is relatively large and would put paid to any current regulation. Direct measurement of the lamp current alone is not possible, and it is, therefore, measured indirectly. This is done by first measuring the total current (winding 1) and deducting from this the current through the capacitor (winding 2 — wound in anti-phase to winding 1).

6

Readers should note the difference between 'duty cycle' and 'duty factor', a source of confusion for many! Duty cycle refers to variations of the load with time. Duty factor is used in pulse techniques and is the ratio of the average pulse width to the average pulse spacing of pulses in a pulse train.

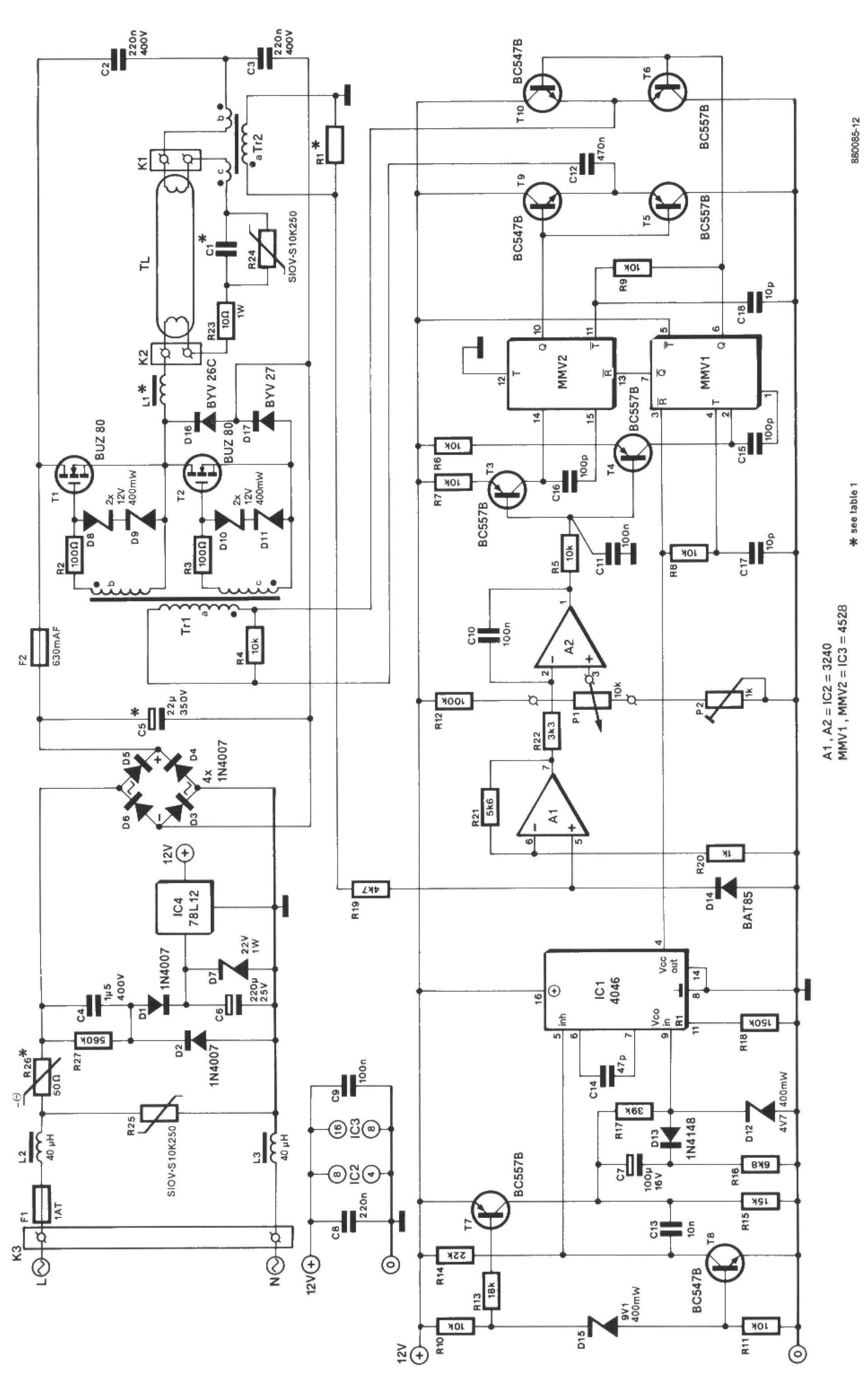



**Fig. 6. Circuit diagram of the HF controller.**

The secondary current of $Tr_2$ is converted into a voltage by $R_1$. Of this voltage, the positive half is amplified by $A_1$ and its average value is then compared with a voltage whose level is preset with $P_1$. If any differences are measured, $A_2$ increases the drive to the bases of $T_3$ and $T_4$, which varies the duty cycle until the two voltages are equal. The minimum lamp current (when the lamp just does not get extinguished) is preset by $P_2$.

## Construction

Since the circuit is connected direct to the mains, it cannot be stressed too much to BE CAREFUL.
The circuit is best constructed and tested in stages. It is strongly recommended to use an isolating transformer during tests on the circuit.
Start with the control section at the centre of the PCB. That is, mount all ICs, except $IC_4$, and all associated components, including the transistors. Resistors $R_1$ and $R_4$ may also be fitted, but the two transformers must wait a little. Potentiometer $P_1$ may also be connected with the aid of three (temporary) short wires.
Apply a stabilized voltage of 15 V in place of the wire links near $C_4$ (earth closer to the edge of the board). Check the output signal of the VCO ($IC_1$ pin 4) with an oscilloscope or frequency meter. This square-wave signal must remain stable at 70–80 kHz for about a second and then drop to 30 kHz ±5 kHz within a few seconds. Any deviations from the stated values of frequency are caused by tolerances in $IC_1$ and must be compensated by small changes in the values of $R_{18}$ and $C_{14}$.
The same square-wave signal should be present across $R_4$, but here it is not a pulse train, but an alternating signal with a peak-to-peak value of about 12 V. Since at this stage there can be no lamp current, the current regulator will automatically optimize the duty cycle.
When the supply input is decreased to less than 11 V, the oscillator should stop functioning. When the voltage is then raised again to 12 V, a new start cycle should commence.
Check the current drawn by the control circuit: this should be 10–15 mA.

## Choke and transformers

Choke $L_1$ and two transformers, Fig. 8 and Fig. 9, are not available commercially.
The choke, $L_1$, is wound on a readily available pot core with an air gap, measuring 30×19 mm, with $A_l$=1,000. The number of turns depends on the tube with which it is intended to be used — see Table 1. Since high voltages occur across the choke, particularly during start-up, it is essential to separate each

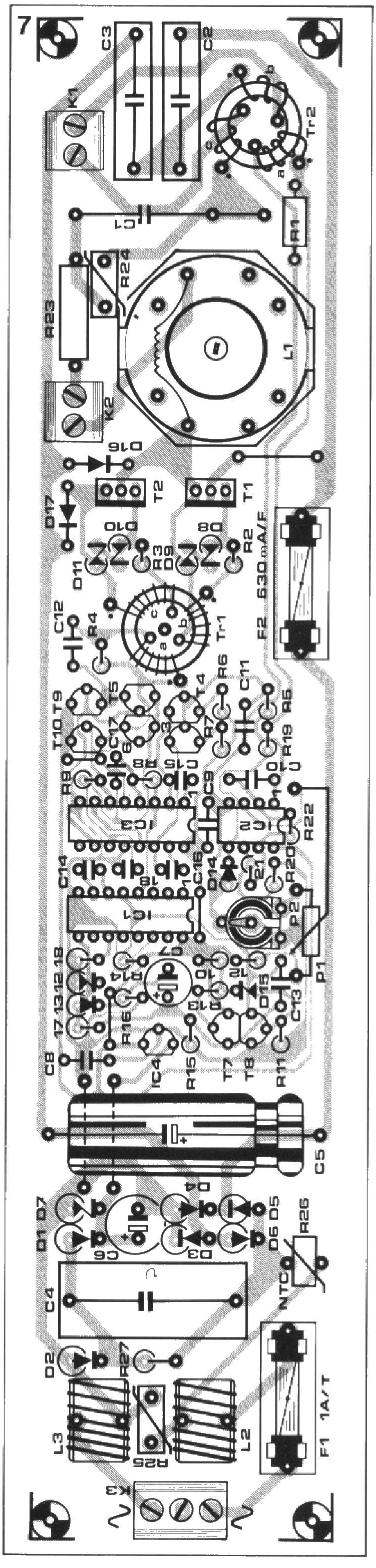



**Fig.7. The printed circuit of the HF controller.**

**Parts list**

Resistors (±5%):

$R_1$ = see text
$R_2$;$R_3$ = 100R
$R_4$ . . . $R_{11}$ incl. = 10K
$R_{12}$ = 100K
$R_{13}$ = 18K
$R_{14}$ = 22K
$R_{15}$ = 15K
$R_{16}$ = 6K8
$R_{17}$ = 39K
$R_{18}$ = 150K
$R_{19}$ = 4K7
$R_{20}$ = 1K0
$R_{21}$ = 5K6
$R_{22}$ = 3K3
$R_{23}$ = 10R; 1 W
$R_{24}$;$R_{25}$ = varistor S10K250 (ElectroValue*).
$R_{26}$ = NTC 50 Ω; 1 W e.g. Mullard no. 2322 610 11509.
$R_{27}$ = 560K
$P_1$ = 1K0 preset
$P_2$ = 10K linear potentiometer with plastic shaft.

Capacitors:

$C_1$ = see text.
$C_2$;$C_3$ = 220n; 400 V
$C_4$ = 1µ5; 400 V
$C_5$ = 22µ; 350 V
$C_6$ = 220µ; 25 V; radial
$C_7$ = 100µ; 16 V; radial
$C_8$ = 220n
$C_9$;$C_{10}$;$C_{11}$ = 100n
$C_{12}$ = 470n
$C_{13}$ = 10n
$C_{14}$ = 47p
$C_{15}$;$C_{16}$ = 100p
$C_{17}$;$C_{18}$ = 10p

Semiconductors:

$D_1$ . . . $D_6$ incl. = 1N4007
$D_7$ = zener diode 22 V; 1 W
$D_8$ . . . $D_{11}$ incl. = zener diode 12 V; 400 mW
$D_{12}$ = zener diode 4V7; 400 mW
$D_{13}$ = 1N4148
$D_{14}$ = BAT85 (Cricklewood)
$D_{15}$ = zenerdiode 9V1; 400 mW
$D_{16}$ = BYV26C (Mullard)
$D_{17}$ = BYV27 (Universal Semiconductor Devices)
$T_1$;$T_2$ = BUZ80 (ElectroValue*)
$T_3$ . . . $T_7$ incl. = BC557B
$T_8$;$T_9$;$T_{10}$ = BC547B
$IC_1$ = 4046
$IC_2$ = 3240
$IC_3$ = 4528
$IC_4$ = 78L12

Miscellaneous:

$F_1$ = fuse 1 A; delayed action
$F_2$ = fuse 630 mA; fast
2 off PCB-mount fuseholders.
$K_1$;$K_2$ = 2-way terminal block for PCB mounting.
$K_3$ = 3-way terminal block for PCB mounting.
$L_1$ = the following parts from Siemens are required for making this inductor:
1 off pot core B65701-L1000-A48;
1 off coil former B65702-B-T2;
2 off washers B65705-A5000;
1 off mounting assembly B65705-B3;
1 off white screw core B65679-E1-X22;
1 off threaded flange B65679-L3;

These parts are listed in the Siemens Preferred Products Catalogue, and are available from ElectroValue*.
L2;L3 = suppessor choke 40 $\mu$H; 2 A.
TR1 and TR2 are wound on 2 ferrite cores Type RK60 (Mullard no. 4322 020 97060).
PCB Type 880085 (see Readers Services page).

* ElectroValue Limited • 28 St Judes Road • Englefield Green • Egham • Surrey TW20 0HB. Telephone: (0784) 33603. Telex: 264475. Northern branch: 680 Burnage Lane • Manchester M19 1NA. Telephone: (061 432) 4945.

layer from the next with good-quality insulating tape. Use enamelled copper wire 24–26 SWG (0.5 mm dia.).
Both transformers are wound on the same type of ferrite toroid. The primary winding of the pulse transformer, $Tr_1$, consists of 40 turns enamelled copper wire, SWG 35 (0.2 mm dia.). Both secondary windings consist of 30 turns enamelled copper wire, SWG 14. It is important that the secondaries are wound in opposite directions from one another to ensure anti-phase drive of the power MOSFETs. Furthermore, the potential difference between the primary and the secondary windings is some 300 V: it is therefore important to keep the secondaries well away from the primary.
The current transformer is fairly easy to make. Both primary windings consist of 2 turns enamelled copper wire, SWG 25 (0.5 mm dia.), wound in opposite directions from one another. The secondary consists of 4 turns of the same wire as the primaries.

## Final construction

Fit $Tr_1$ and $Tr_2$ in position on the PCB, followed by $R_2$, $R_3$, $D_8$, $D_9$, $D_{10}$, $D_{11}$, $T_1$, and $T_2$. Apply a voltage of 12 V from an external source and ascertain the current drawn: this should be 20–25 mA after about 5 seconds (i.e., at the normal operating frequency).
Next, check that the secondary windings are in anti–phase by temporarily interconnecting the source connections on the PCB and verifying that there is NO signal between the two gate connections. Then, mount $K_3$, $F_1$, $L_2$, $L_3$, $R_{25}$, $R_{26}$, $R_{27}$, $C_4$, $C_6$, $D_2$ and $D_7$. With a suitable mains cable, connect $K_1$ to the mains and switch on. Measure the voltage across $D_7$, which should be 18 V. REMEMBER YOU ARE NOW WORKING WITH MAINS VOLTAGES!
Disconnect the mains from $K_1$, discharge $C_6$ through a resistor, and mount $IC_4$. Then, fit the two wire links near $C_5$ (but not yet this capacitor). Again, connect the mains to $K_1$ and check the output of $IC_4$ as 12 V. Afterwards, measure

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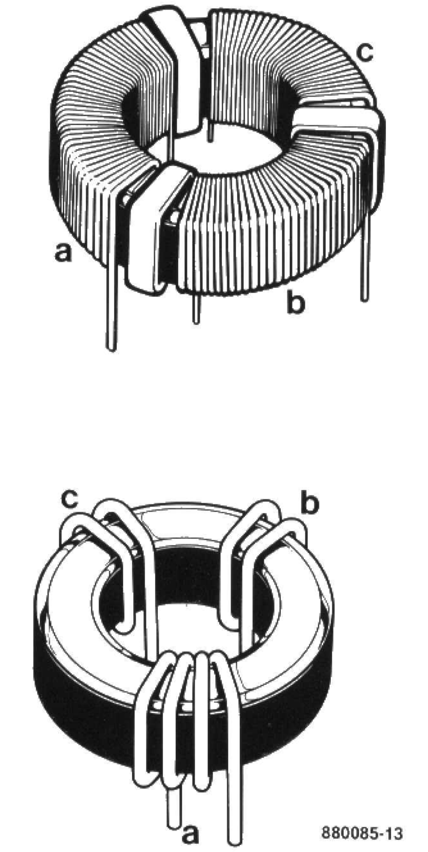


**Fig. 8. Showing how the pulse transformer (a) and the current transformer (b) should be wound.**

the gate signal with an oscilloscope (compare with Fig. 5a upper trace.).
Finally, mount all other components, and do not forget the wire link near $T_1$. The values of $C_1$, $L_1$, and $R_1$ are given in Table 1. Take care not to confuse $D_{16}$ with $D_{17}$: these components look very much alike!
When tubes with a power rating >30 W are used, it is advisable to mount $T_1$ and $T_2$ on a simple heat sink: an L-shaped piece of aluminium as shown in Fig. 10 is sufficient. Note, however, that the MOSFETs must be insulated from the heat sink. In view of the relatively high potentials involved, use ceramic, not mica, insulating washers.

## Assembly and connecting-up

Connect the tube to the circuit, turn $P_2$ completely anti-clockwise, set $P_1$ to the centre of its travel, take a deep breath, and connect the mains. The tube should light after 1–2 seconds and it should be possible to dim it with $P_1$. It is possible that you experience odd running-light effects in the tube: these may be eliminated by turning the adjustment screw in the core of $L_1$.
Set $P_2$ to a position where the tube just remains lit. It will be noticed that a

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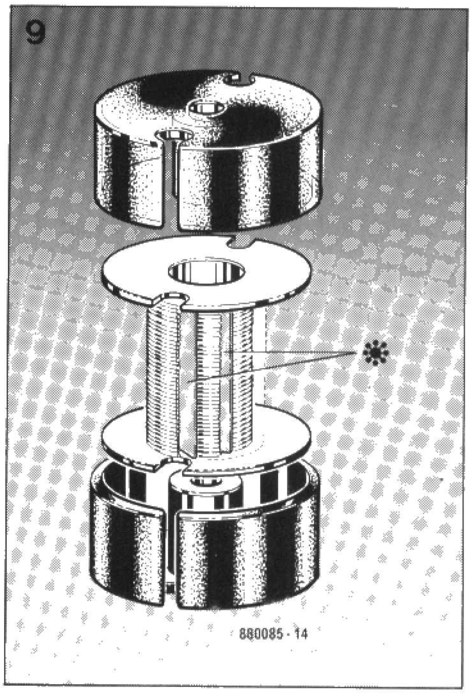


**Fig. 9. Showing how choke $L_1$ should be wound. The number of turns for a variety of tubes is given in Table 1.**

Table 1

| Tube rating | $L_1$ | $C_1$ | $R_1$ |
|---|---|---|---|
| 20 W | 2.0 mH<br>45.5 turns | 4n7<br>1500 V | 2R2 |
| 30 W | 1.8 mH<br>43.5 turns | 5n6<br>1500 V | 1R8 |
| 40 W | 1.6 mH<br>42.5 turns | 6n8<br>1500 V | 1R8 |
| 60 W | 1.1 mH<br>32.5 turns | 10 n<br>1500 V | 1R0 |

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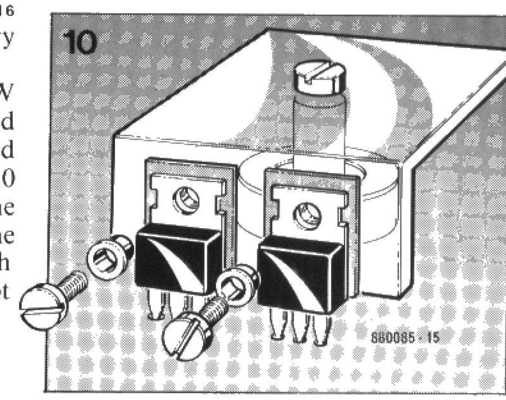


**Fig. 10. When fluorescent tubes of rating >30 W are used, the MOSFETs should be cooled, for example, with the aid of a simple L-shaped piece of aluminium as shown here.**

warm tube can be dimmed to a larger degree than a cold one. It is, therefore, best to set $P_2$ when the tube is cold.
In view of the operating frequency and the waveform of the output signal of the circuit, the connections between the cir-

Continued on p. 43

# PAINTBOX: THE HIGH TECH APPROACH TO ARTISTIC CREATIVITY

by John Spurling*

**David Hockney's PAINTBOX painting.**

The great technical innovations of art have seldom been observed or reliably recorded in their early stages. Jan Van Eyck, at the beginning of the 15th century, was probably the first artist to make masterly use of oil painting, though he was not, as is sometimes supposed, its inventor.

Watercolour in the most general sense is a very ancient technique, but its full development did not take place until the 18th and 19th centuries in England. Graphite sticks seem to have been invented in the 16th century, but not until 1790 did the French chemist, Nicolas-Jacques Conté, manage to control their hardness and softness and transform them into "lead" pencils that have been used by artists ever since.

The use of brushes, on the other hand, goes back to ancient China and Egypt, and the Stone Age in Europe.

PAINTBOX[1] is a different matter. Originally unveiled in 1981 by Quantel[2] and continually refined since, it is basically a tool for graphic design on television, an electronic system for producing and editing images with great speed and sophistication.

One might loosely describe it as the visual version of a word processor, but instead of tapping out letters on a keyboard, the user sits in front of a smooth surface or table and simply draws or paints on it with an electronic stylus on the end of a wire. The result appears immediately on a television

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*John Spurling is art critic of the *New Statesman*.

monitor and there you can also mix a virtually limitless range of electronic colours. You use a cursor to pick them out and apply them, much as a word processor operator sends in his cursor among text to shape and colour his sentences.

## Thinking aloud

To watch a novelist or a poet composing on a word processor would probably send a television audience to sleep. How would it be, though, if an artist — as opposed to a designer or editor — were let loose on PAINTBOX?

In a series of BBC TV programmes shown in Britain last year under the title 'Painting With Light', several artists with international reputations made the experiment. If the results were not yet quite as convincing as Van Eyck's exploitation of oil paint, the process made intermittently interesting viewing.

The artists — struggling manfully to understand and master the possibilities of the new medium — were assisted by a technician and chatted and thought aloud as they worked. What they said was often more telling than the images they produced on the screen, but then these were all well established people whose ideas, techniques and dodges have been developed over many years in quite different media. It was a little like asking Turner to paint a Persian miniature or Van Gogh to fool around with collage — curious, but slightly unfair.

David Hockney, the first of the artists, and a great one for technical experiments, was typically enthusiastic, saying: 'A barrier has gone. Now there is nothing between the viewer and the artist. What you are seeing developing on your television is the inside of the artist's head.'

The United States artist Larry Rivers, trying to adapt his habitual technique of painting over photographs to this new machine, sounded more frustrated: 'I feel as if I am working with one hand tied behind my back. It is a situation in which colour is light, but when I start to mix, I don't like what I get.'

## Strangely frightened

He kept his sense of humour, however, especially when attempting a portrait of a well-known pop star, saying: 'I am going to spend five minutes on your nose.' Bending down over his electronic stylus, Rivers did look a bit like a cosmetic surgeon — or perhaps a dentist with his drill.

The British artist Richard Hamilton specializes in collages with pop associations — images lifted from advertisements and press photographs. One might have expected PAINTBOX, with its formidable cut-and-paste facilities and editorial wizardries, to be just his thing. But although he did admit that he was beginning to feel he should have one in his studio, Hamilton seemed strangely frightened of the machine.

He seldom trusted himself actually to handle the stylus, but mainly worked by issuing instructions to the technical assistant, and he was painfully cautious and undemanding in what he committed to the screen. He scarcely called on PAINTBOX's mighty range of colour and, having started with a rather powerful photograph of Protestants marching in Northern Ireland, he contrived by the end only to weaken and confuse it.

Howard Hodgkin, a winner of the Turner prize and noted for his small, densely painted and brilliantly coloured abstracts and figurative subjects, was much more adventurous than Hamilton, but still distinctly put out by the experience. The main problems for him were the lack of texture and the speed at which he was required to work.

Since he sometimes takes two or three years to finish a painting, this was hardly surprising. Even so, he managed to make the screen look just like a Hodgkin painting, or rather some ten Hodgkin paintings in succession, since he kept covering up one with another.

## Medium of the future?

But whereas in an oil painting these successive layers would leave some trace of themselves in the finished work, adding to its depth and richness and often actually altering one's perception of the surface without appearing to do so, in a PAINTBOX creation they simply vanish as if they have never been. It proved, perhaps, what the politicians in last year's general election campaign had strongly suggested: that what you see on your television screen is all veneer.

It may be that PAINTBOX and its no doubt still more sophisticated successors will become the artistic medium of the future and make brushes, pencils, watercolours, oil paints and the rest obsolete, but I fancy not. Time, as Hodgkin demonstrated, is as important to art as technique — the time put into it and the time required to assimilate it.

The very qualities that make PAINTBOX such an ideal tool for television news items, commercials, animated sequences, and so on, make it little more than a toy for artists, since nothing is left of the process once the result is reached and so the result can only hold the attention for a few seconds.

What made good watching was the artists at work, not their works of art. But, of course, it is perfectly possible that there is an artist not yet known or born who will coax depth from the superficial and time from the instantaneous in some quite unimaginable way.

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**References.**

1. **Paintbox, c/o BBC Enterprises Ltd, 80 Wood Lane, London W12 0TT.**
2. **Quantel, Kiln Road, Shaw, Newbury, Berkshire RG13 2HA.**

**From page 41**

cuit and the tube must be kept short. In practice, that means that the circuit will have to be built into the armature. This has been taken into account during the design of the PCB. Make sure that there will be at least 6 mm (¼ in) space between live parts of the board and metal parts of the armature. The existing starter and choke may, of course, be removed.

Potentiometer $P_1$ is connected to the PCB by a 3-core cable: remember that it is connected to the mains (neutral) via $P_2$ and $L_3$! It is, therefore, advisable to use a potentiometer with a man-made fibre spindle.

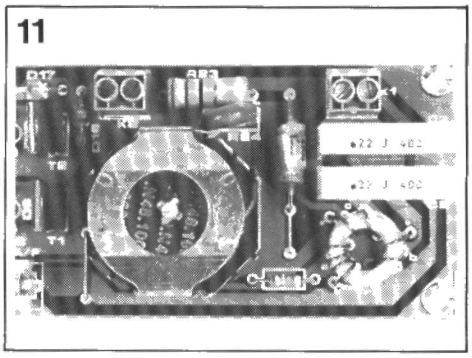



**Fig. 11. The current transformer and choke $L_1$.**

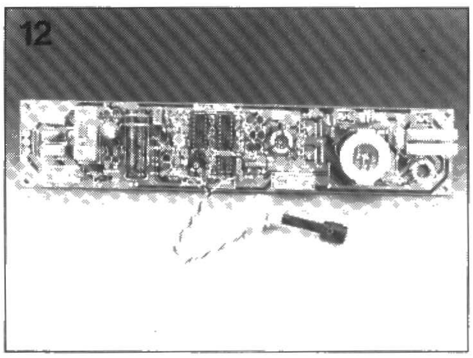



**Fig. 12. Completed HF controller ready for fitting into the tube armature.**

# MICROCONTROLLER-DRIVEN POWER SUPPLY — 2

This month we deal with the operation, construction and setting up of the intelligent power supply.

Details on the operation of the microcontroller-driven power supply are purposely arranged to precede those on construction and setting up in order to provide good insight in the interaction between the instrument's software and hardware.

## Controls, functions and operation

Figure 9 shows the layout of the front panel for refererence in the description of the various instrument controls. The self-adhesive front panel foil with integrated membrane switches is available ready-made through the Readers Services.

Only two components on the front panel are not controlled by the 8751: the on/off switch and the MAX LED beside the digital current read-out. This LED ($D_5$ in Fig. 8) is driven by $IC_2$ (Fig. 2) via the controller board.

The basic function of the rotary contact encoder (SETTING) was already discussed in Part 1 of this article. The encoder has significant advantages over conventional UP/DOWN or "+/–" switches on microprocessor controlled equipment. Such switches are often found to operate either too slow or too fast. The contact encoder can be operated as a multiturn potentiometer (that is, one without an end stop).

• •

Rotary control **SETTING**
**U/I** switch
**U/I** LED bars
**SET** LEDs
**Displays**

The 7-segment LED displays will normally indicate measured output voltage and current. This means that the SET LEDs beside these displays will mostly be off. The analogue voltage meter has two measuring ranges, enabling reasonably accurate readings. The scale selection is indicated by a LED mounted next to the relevant LED bar. Scale selection is performed automatically at a switching threshold of 10 V. The analogue meters display set and measured values of voltage and current simultaneously. The user-defined (set) value is displayed on a dot scale, the measured value on a bar scale. Misinterpretation of the indications is virtually impossible because measured values can not exceed set values.

Output voltage and current limit theshold of the power supply are set by turning the SETTING control, and pressing the U/I membrane switch if required. The LED inside this switch indicates selection between current limit (LED on) or output voltage (LED off). The LED is turned off automatically when the setting remains unchanged for longer than about 5 seconds.

When SETTING is operated, LED SET to the right of the relevant digital read-out (V or I) lights, and the 7-segment displays show the set value. The measured value is displayed automatically again 2 seconds after the last change in the setting.

• •

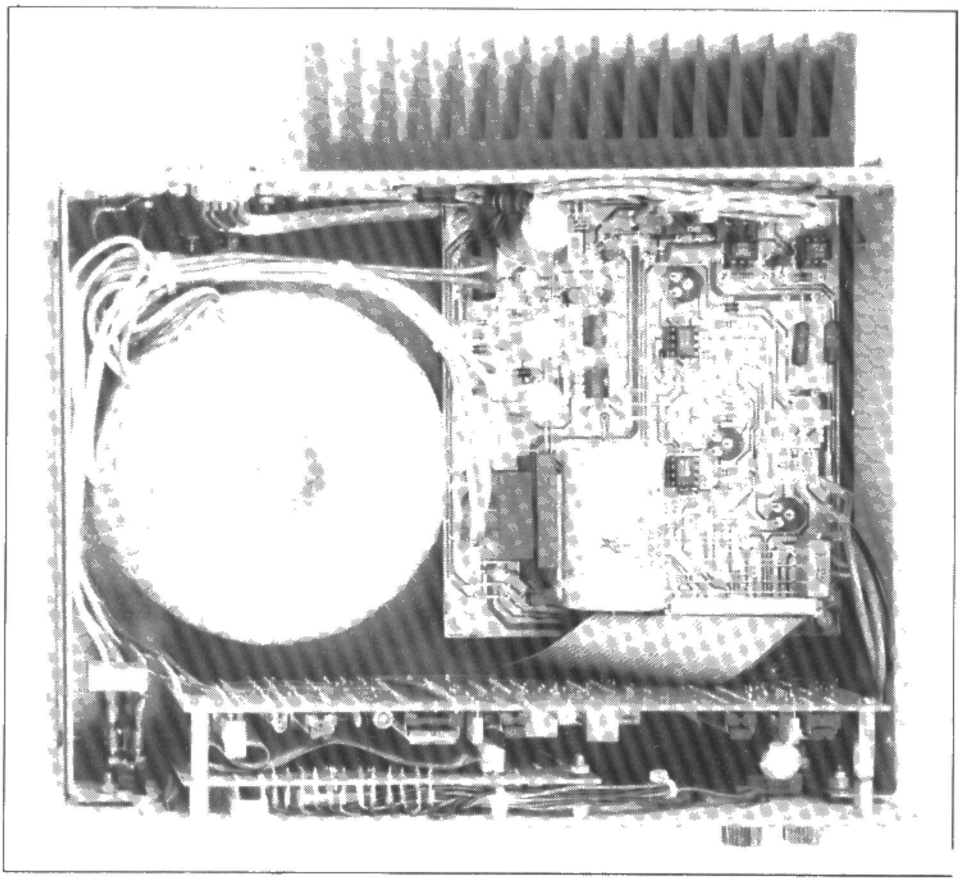
**0 V OUT** switch
**0 V OUT** LED

Pressing the 0 V OUT membrane switch causes the output voltage to be made nought immediately without changing the supply settings. This facility is indispensable for preventing damage to incorrectly operating loads, and is much faster and safer than having to switch off the supply completely to modify the settings. The supply is automatically started in the 0 V OUT mode at power-on.

• •

**HOLD/TRACK** switch
**HOLD** LED

The switch is disabled when function 0 V OUT is active. The HOLD function is used for changing the power supply settings without affecting output voltage (HOLD LED lights). The new settings are not put into effect until HOLD/TRACK is once more pressed to select the TRACK



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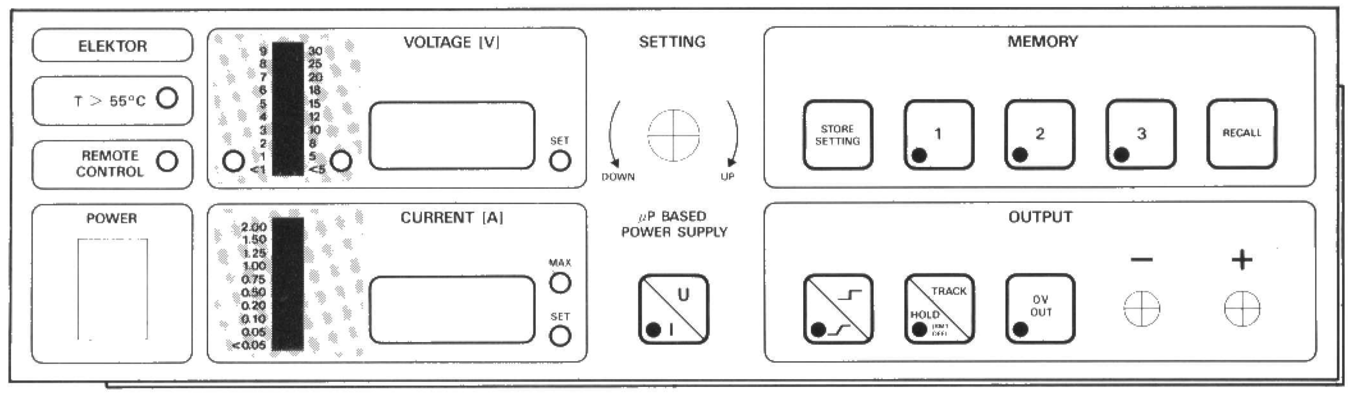


**Fig. 9. The ready-made front panel foil for the microcontroller-driven power supply has built-in membrane switches, and semi-transparent bezels for the displays and LEDs.**

function (HOLD LED is off). HOLD also disables the serial input of the supply, so that commands from the control computer are ignored (RMT OFF = ReMoTe control OFF).

• •

**SLOPE** switch
**SLOPE** LED

This function makes it possible to select between two rates of rise of the supply output voltage following a sudden change in the settings (as, for example, after cancelling the 0 V OUT function). The "slow" slope causes the output voltage to reach the desired value after 0.5 s. When the "fast" slope is selected, the voltage change is effected as fast as possible. The "slow" position is intended for analogue and, in particular, audio circuits where it can help to eliminate power-on clicks. The "fast' position is selected for digital circuits, which generally require short rise times of the supply voltages. Also, power-up reset circuits may not operate correctly when the nominal supply voltage is reached too slowly.

• •

**MEMORY**

The resident memory in the power supply can hold three user-defined settings. Each setting comprises three parameters: set voltage, set current limit, and response slope. With reference to the switch locations in the MEMORY area on the front panel, the memory functions are always controlled from the left to the right.
Programming commences by pressing STORE SETTING. The LEDs in keys 1, 2 and 3 will light for about 2 s while the set values of voltage and current are displayed on the digital read-out. To store a setting in memory, one of the three numbered keys is pressed within 2 s. Memory 1 differs from 2 and 3 in that its contents are loaded and used as the default supply settings at power-on when the user cancels the 0 V OUT function. Set values can be checked by just pressing STORE SETTING, but the contents of the memories can also be called up for inspection by pressing the key with the relevant memory number. The V and I contents will be displayed for 2 s on the digital read-out.
Stored supply settings are called up by first pressing the relevant memory key followed by the RECALL key. When function 0 V OUT is activated, the stored setting will be loaded, but no voltage is applied to the output until 0 V OUT is cancelled.

## Construction and finish: general hints

No particular problems are envisaged in the construction of the power supply. Wiring is also relatively simple when flatcable and appropriate IDC (press-on) connectors are used. The functional units in the supply correspond to the three circuit diagrams discussed last month. To these comes the self-adhesive front panel foil with integrated membrane switches. The front panel itself is a fairly rugged component, but not the flatcable that extends from it. Be sure that this is never folded, twisted or subjected to excessive strain: the damage caused will be irreparable!
The size of the front panel (min. 24.5×7 cm; max. 26×9 cm) and that of the mains transformer determine the choice of a metal enclosure for the supply. Due attention should be paid to electrical safety, which is best ensured by using the stated double-pole mains switch, mains entrance and power transformer, wired as shown in Fig. 2. Do not forget to connect earth to the metal enclosure.

## Regulator board

Most of the parts shown in the circuit diagram of Fig. 2 are accommodated on the single-sided printed circuit board of Fig. 10. A number of wire links on this board carry supply currents for the other two boards. It is, therefore, recommended to use relatively thick insulated wire (dia. 0.5 to 0.8 mm) where appropriate. Also, each of the supply connections between the boards is made in two parallel wires in the flatcable, in combination with two connector pins.

Pay attention to the polarity of the electrolytic capacitors (particularly $C_4$) before these are mounted on the board. To aid in their cooling, power resistors $R_9$ and $R_{10}$ must be fitted about 1 cm above the board surface. The cooling can be further improved by winding a loop in the terminals where they leave the resistor body. The resistor is then supported by its own terminals, and can not cause PCB islands or tracks to come loose.
Use sockets for $IC_1$ and $IC_2$ to prevent difficulties during the setting up. Keep the terminals of MOSFET $T_1$ short-circuited with a piece of left-over component wire while soldering this static-sensitive part onto the board.
The control board is positioned such that the "$IC_3$ side" is close to the heat-sink for which a clearance is cut in the rear panel of the enclosure. Components $D_7$, $T_4$, $T_5$ and $IC_3$ are fitted onto the heat-sink — see Fig. 11. The temperature sensor is pushed securely in a 4.5 mm hole. Regulator $IC_3$ and the power transistors must be fitted with insulating mica washers and plastic bushes to prevent short-circuits via the heat-sink. Do not forget to apply a generous amount of heat-sink compound. Power resistors $R_{18}$ and $R_{19}$ are connected direct to the emitter terminals of $T_4$ and $T_5$ as shown in Fig. 12.
The completed control board should be tested before it is fitted in the enclosure. To do this, the PCB is temporarily wired to the external components in accordance with the circuit diagram of Fig. 2. However, $D_7$ need not be connected as yet, and the 33 V (36 V) winding of the mains transformer is connected to points L and M because the power reduction relay is not yet operational. Inputs $U_{set\,U}$ and $U_{set\,I}$ are temporarily connected to ground, and all other inputs and outputs are not connected.
Apply power, and check the presence of the correct supply voltages on the inte-

**Parts list**

REGULATION BOARD. CIRCUIT DIAGRAM:
FIG. 2 IN PART 1

Resistors:
$R_1$;$R_{14}$;$R_{23}$;$R_{25}$;$R_{26}$ = 1K0
$R_2$ = 10KF
$R_3$ = 1K8
$R_4$ = 2K74F
$R_5$ = 1K21F
$R_6$;$R_8$ = 470R
$R_7$ = 100R
$R_9$;$R_{10}$ = 1R0; 4 W, Type CW-2B-13 (Dale).
$R_{11}$ = 15K4F
$R_{12}$ = 220K
$R_{13}$;$R_{15}$ = 10K
$R_{16}$;$R_{17}$ = 2K7
$R_{18}$;$R_{19}$ = 0R22; 0.5 W
$R_{20}$ = 1K5; 1 W
$R_{21}$ = 82K
$R_{22}$ = 100K
$R_{24}$ = 150R
$P_1$ = 500R preset H
$P_2$ = 1K0 multiturn preset
$P_3$;$P_4$ = 10K preset H

Capacitors:
$C_1$ = 220μ; 63 V
$C_2$;$C_5$;$C_6$;$C_{10}$;$C_{12}$ . . . $C_{16}$ incl.;$C_{21}$;$C_{24}$ = 100n
$C_3$ = 470p
$C_4$ = 4700μ; 63 V
$C_7$ = 1μ; 63 V
$C_8$ = 1000μ; 25 V; radial
$C_9$;$C_{20}$ = 220n
$C_{11}$ = 47μ; 16 V; radial
$C_{17}$ = 120p
$C_{18}$;$C_{19}$ = 470μ; 40 V; radial
$C_{22}$ = 2μ2; 40 V
$C_{23}$ = 1μ0; 25 V
$C_{25}$ = 100n; 400 V

Semiconductors:
$B_1$ = B80C1500 (80 V; 1.5 A)
$B_2$ = B80C5000 (80 V; 5 A)
$D_1$ . . . $D_4$ incl.;$D_8$ . . . $D_{11}$ incl. = 1N4148
$D_5$;$D_6$;$D_{12}$;$D_{13}$ = 1N4001
$D_7$ = LM335Z (National Semiconductor).
$T_1$ = BS170 (ITT Semiconductors).
$T_2$;$T_3$;$T_7$ = BC547
$T_4$;$T_5$ = TIP142
$T_6$ = BC517
$IC_1$;$IC_2$ = 741
$IC_3$ = 7805
$IC_4$ = 7812
$IC_5$ = 7912
$IC_6$;$IC_7$ = 4N25

Miscellaneous:
$F_1$ = fuse; 1 A; delayed action.
Euro-style mains entrance socket with built-in fuseholder.
$S_1$ = DPDT mains switch Marquardt Type 1852.1102.
Insulation material for $T_4$, $T_5$ and $IC_3$.
Common heat-sink for $T_4$ en $T_5$ (e.g. Fischer Type SK85 50 mm).
$Re_1$ = PCB mount relay; coil voltage 5 V; e.g. Siemens Type V23127-B0001-A101.
$Tr_1$ = toroidal mains transformer; secondary rating: 15 V/4 A; 18 V/4 A; 9 V/0.8 A; 15 V/0.25 A. ILP no. ILP-5C677 (240 V primary); 5C517 (220 V primary).
$K_1$ = gold-plated PCB mount header; 2 rows of 15 contacts (pitch: 2.54 mm).
$K_2$ = male 9-way sub-D connector.
PCB Type 880016-2 (see Readers Services page).

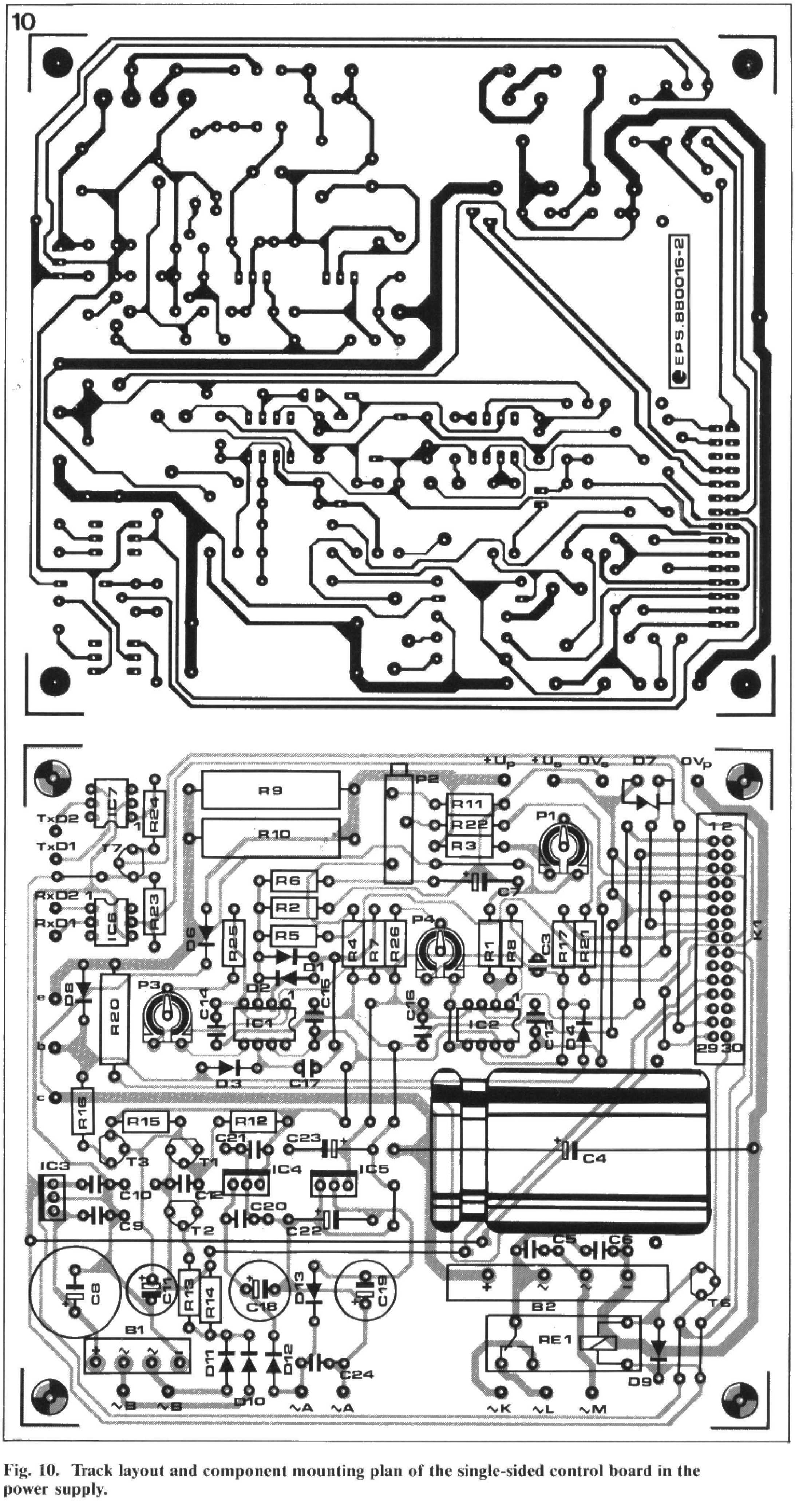


Fig. 10. Track layout and component mounting plan of the single-sided control board in the power supply.

grated circuits and the relevant pins on connector $K_2$. Switch off, and remove the ground connections of $U_{set\,U}$ and $U_{set\,I}$. Build and connect the auxiliary test circuits of Fig. 13 — these allow $U_{set\,U}$ to be set between 0 and 3.5 V, and $U_{set\,I}$ between 0 and 0.15 V. Set $P_{set\,I}$ to the centre of its travel, and apply power again. Measure the supply output voltage, and check that this can be varied by adjusting $P_{set\,U}$. Likewise, check the operation of the current limiter by setting $P_{set\,U}$ to the centre of its travel, and measuring the output current, which should have a range of 0 to about 250 mA. This test should not last longer than 20-30 seconds if $T_4$ and $T_5$ have not yet been fitted on the heat-sink. The operation of the supply shutdown function is best checked with the aid of an oscilloscope connected to the supply output terminals. Set $P_{set\,U}$ to 0 V and verify that the scope does not show voltage transients while switching the supply on and off a few times. When an oscilloscope is not available, a LED and a 470 Ω series resistor may be used. In the event of the LED lighting briefly at power-on, the shutdown circuitry is faulty, and it should be examined with reference to the functional description given in Part 1.

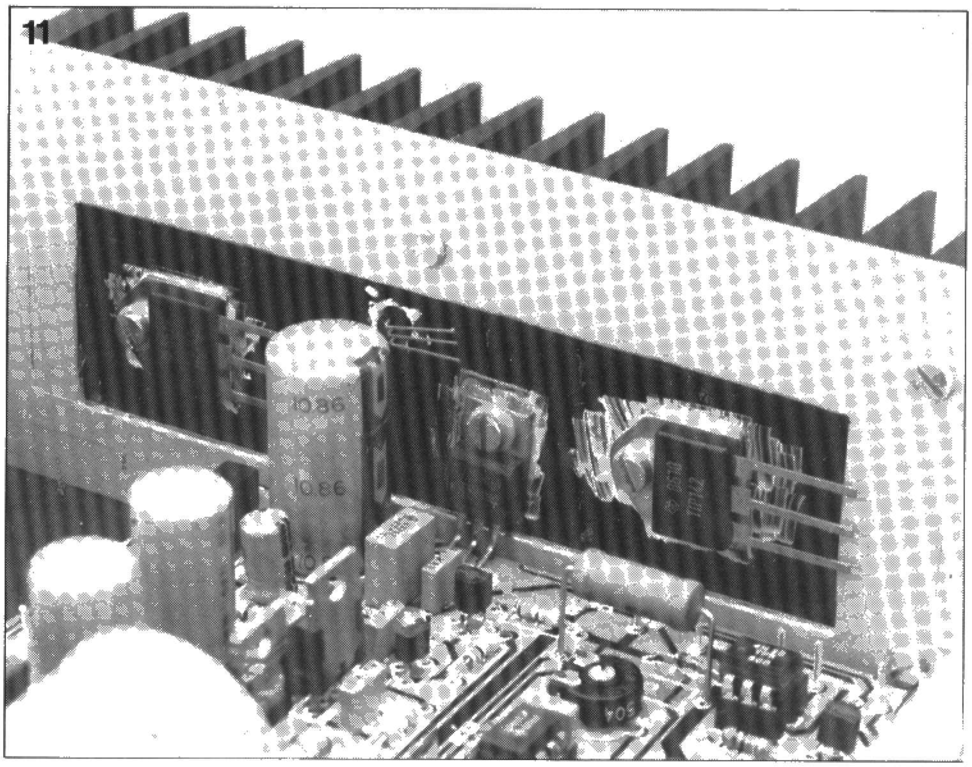


**Fig. 11. Three power semiconductors and one temperature sensor fitted onto a common heat-sink, which is accessible from the inside of the enclosure through a rectangular clearance in the rear panel.**

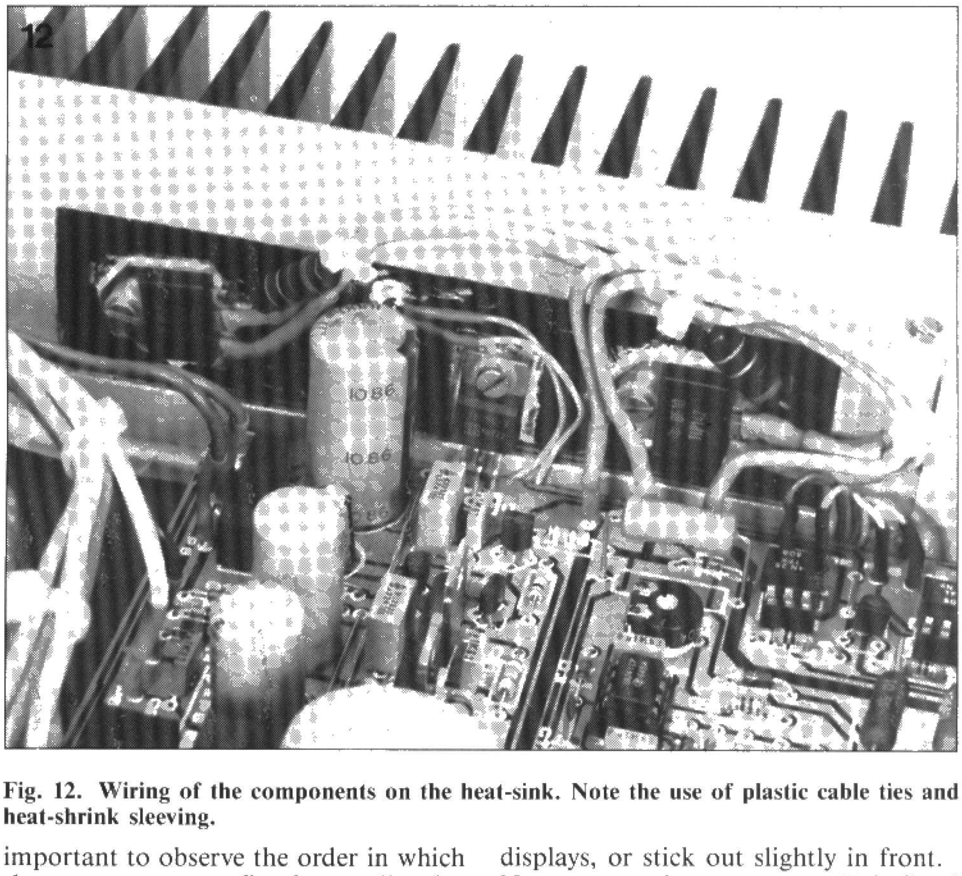


**Fig. 12. Wiring of the components on the heat-sink. Note the use of plastic cable ties and heat-shrink sleeving.**

## Display board

The layout of the double-sided, through-plated display board shown in Fig. 14 corresponds to the circuit diagram of Fig. 8. When completing the board, it is important to observe the order in which the components are fitted, as well as individual height. Commence the construction with fitting the transistors and resistors in the usual manner. The total height of the board is determined by the that of the LED bars and the 7-segment displays. It is recommended to mount these in IC sockets because of the height of $S_{10}$, and to obtain a level display surface. Fit the 3 mm LEDs, making sure that the tops of these are level with the displays, or stick out slightly in front. Next, mount the connectors. $K_1$ is fitted at the copper side of the display board as shown in Fig. 15. Cut off the connector pins at the component side of the board to make sure that enough room is left for mounting $S_{10}$. In addition to connection terminals, the rotary contact encoder has four pins to enable it to be fitted securely onto the printed circuit board. Again, observe that it does not touch any of the pins of $K_1$. Two types of rotary encoder

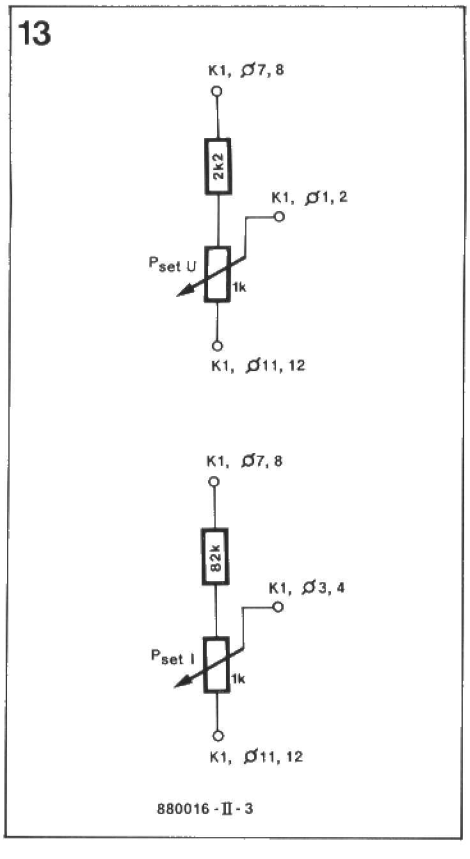


**Fig. 13 Auxiliary potentiometer circuits for testing the control board.**

from Bourns may be used as discussed in Part 1 of this article. Suitable types are stated in the Parts List to Fig. 14.

## Front panel: look before you leap

The preparation of the front panel requires careful consideration of various points related to mechanical construction. To begin with, the drilling template supplied with the PCB is used for punching holes in the metal front panel of the enclosure. It is possible to make a photocopy of the drilling template, provided the dimensions are accurately checked. The corners of the rectangular holes are also marked with the centre punch before jig-sawing and filing them to size.

The photograph on the first page of this article shows how the display and processor PCB are secured vertically behind the front panel. It is recommended to use metal PCB spacers with internal threading at both ends. The spacers can be secured onto the front panel with countersunk screws *before* fitting the front panel foil. Alternatively, the spacers can be glued onto the rear of the front panel.

The next step is the mounting and glueing of the LEDs not accomodated on the display board. Apply glue *after* securing the LED in the relevant hole, and allow ample time for hardening before connecting the LED terminals.

The front panel foil must not be mounted until all testing and building to be described is completed successfully. For the purpose of testing the processor PCB it may, however, be secured temporarily on the front panel using double-sided adhesive strips (be extremely careful handling the flat cable).

## Processor board

The layout of the double-sided through-plated processor board is given in Fig. 16. The corresponding circuit diagram is Fig. 6. The completion of this board in accordance with the component overlay is a matter of routine. It is strongly recommended to use sockets for all ICs. The SEEPROM is fitted in its socket as the very last component (never press RECALL until the SEEPROM is fitted: the processor will ''hang up'', i.e, not respond to further commands). The fitting of configuration diodes $D_{12}$, $D_{13}$ and $D_{14}$ will be reverted to in Part 3 of this article. For the moment, these components need not yet be fitted. Similarly, $D_{15}$ (if at all required) need not be mounted until the test phase is completed.

Connect $C_{20}$ direct onto pins 20 and 40 of $IC_1$ at the copper side of the board. The microcontroller for this project can only be programmed by *Elektor Electronics*. Each and every programmed

14

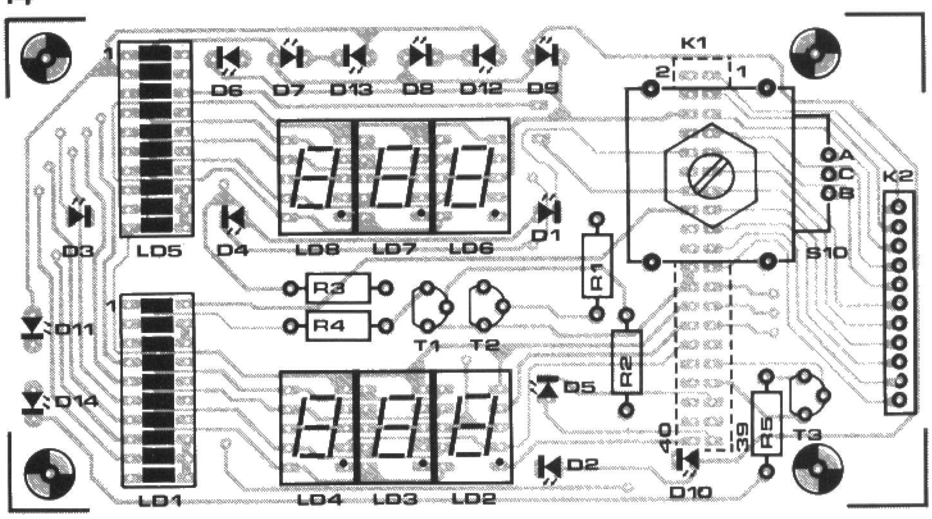


**Fig. 14. Component overlay of the double-sided, through-plated, display board.**

**Parts list**
DISPLAY BOARD. CIRCUIT DIAGRAM:
FIG. 8 IN PART 1

Resistors:

$R_1$;$R_2$ = 4K7
$R_3$;$R_4$ = 47R
$R_5$ = 470R

Semiconductors:

$D_1$ . . . $D_{14}$ incl. = LED; red; dia. 3 mm.
$T_1$;$T_2$ = BC516
$T_3$ = BC547
$LD_1$;$LD_5$ = LED-bar with 10 LEDs in 20-way DIL enclosure; e.g. MV57164 (General Instrument Opto-Electronics).
$LD_2$;$LD_3$;$LD_4$;$LD_6$;$LD_7$;$LD_8$ = HD11070 (Siemens).

Miscellaneous:

$S_1$ . . . $S_9$ incl. = membrane switches integrated in front panel foil.
$S_{10}$ = contact encoder ECW0J-B24-AC0006 (24 pulses/rev.) or ECW0J-B24-AC0009 (36 pulses/rev.). Supplied with metal support plate for PCB mounting (Bourns).
$K_1$ = PCB-mount header: 2 rows of 20 contacts (pitch: 2.54 mm).
$K_2$ = 11-way PCB-mount edge connector for flat foil cable from membrane keyboard; e.g. Type 7583 (Molex).
Metal enclosure: e.g. Retex Octobox.
PCB Type 880016-3 (see Readers Services page).
Front panel foil Type 880016-F (see Readers Services page).

15

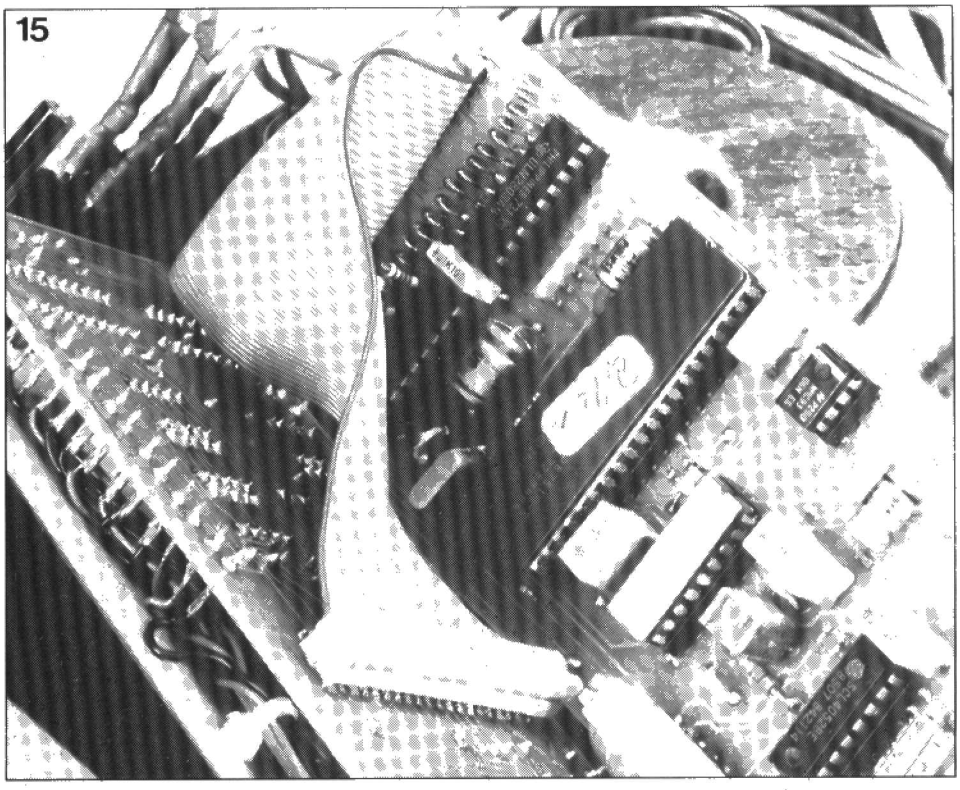

**Fig. 15. Flatcable connection between display and processor board.**

8751 will be tested in a prototype of the power supply. The machine code in the on-chip EPROM is copy-protected, and reading of the EPROM contents is impossible even with special programmers or development systems.

## Wiring and testing

After completing the processor PCB it is time to wire the supply in accordance with the circuit diagrams. Sense inputs $U_s$ and $0V_s$ of the voltage regulation circuit should be connected to the supply outputs, $U_P$ and $0V_P$, exactly as shown in the circuit diagram, i.e., *direct on the supply output terminals*. The practical construction is shown in the photograph of Fig. 17. Each output terminal has two wires attached: + to $+U_s$ and $+U_P$, and − to $0V_s$ and $0V_P$.
The front panel foil is mounted provisionally (use blu-tack or double-sided tape), and the cable is fed through the slot in the front panel. Push the end securely in $K_2$. Once more check all wiring and components for correct mounting. Do not yet fit the ICs.
Apply power to the unit, and check the supply voltage on all IC sockets. Switch off, and fit all ICs with the exception of the SEEPROM. Switch on again. The LED beside the analogue voltage meter, and that for 0 V OUT, should light. The least significant digit on the digital displays may have an instability of ±1 digit, but this is normal. LEDs $I_{set}$ and $U_{set}$ light briefly immediately after power-on.

There is no reason to panic when the circuit fails to operate as described above. Use an oscilloscope to check the presence of the ALE/P signal on pin 30 of the microcontroller. The frequency of this signal should be about 1 MHz. The multiplex signals for the displays have a repetition time of about 1 ms. If necessary, their presence should be checked over the whole path from Port P1 on the controller, via drivers, connectors and flat cable right up to the display PCB. Signals from Port P0 can be checked likewise, but they are not as steady as those from P1.
Press 0 V OUT: the associated LED should light. This indicates correct operation of the keyboard. Operate SETTING. The value shown on the voltage displays should increase as this control is turned clockwise (max. 30 V), and decrease when it is turned counter-clockwise. Check $U_{set\,U}$, which should vary between 0 and 3.5 V when the read-out varies correspondingly between 0 and 30 V. $U_{set\,U}$ can be measured on pins 1 and 2 of $K_2$ on the processor PCB, or on $R_5$ on the control PCB (terminal closest to $R_4$). Use the positive supply output, $+U_P$, as ground for the measurement. When the last mentioned test checks out, the circuit around $IC_2$ and $IC_6$ on the processor board works all right.

**Parts list**
PROCESSOR PCB. CIRCUIT DIAGRAM:
FIG. 6 IN PART 1

Resistors:
$R_1$ = 33K2F
$R_2$;$R_7$ = 10KF
$R_3$ = 8K25F
$R_4$ = 10K
$R_5$;$R_8$ = see text.
$R_6$;$R_{10}$ = 2K74F
$R_9$ = 1K21F
$R_{11}$ = 8K2
$R_{12}$;$R_{13}$ = 1K0F
$R_{14}$ = 15K
$R_{15}$ . . . $R_{22}$ incl. = 15R
$R_{23}$ = 4K7 8-way 9-pin single-in-line (SIL) resistor array.

Capacitors:
$C_1$;$C_{12}$ = 33p
$C_2$;$C_6$ = 330n
$C_3$ = 560n
$C_4$;$C_5$ = 10n ceramic
$C_7$ = 1μ; 16 V
$C_8$ = 220n
$C_9$;$C_{10}$ = 330p
$C_{11}$ = 10μ; 10 V
$C_{13}$ = 100μ; 10 V
$C_{14}$;$C_{16}$;$C_{17}$;$C_{18}$ = 100n
$C_{15}$ = 10μ; 16 V
$C_{19}$ = 22n
$C_{20}$ = 100n

Semiconductors:
$D_1$ . . . $D_{15}$ incl. = 1N4148
$IC_1$ = 8751H(-12) *Elektor Electronics* order no. ESS 563. See text and Readers Services page.
$IC_2$ = PM-7548 (PMI).
$IC_3$ = DAC0831 (National Semiconductor).
$IC_4$ = TL501C (Texas Instruments).
$IC_5$ = 4052
$IC_6$ = LF412A (National Semiconductor) or OP-14A (PMI).
$IC_7$ = NMC9306 (National Semiconductor).
$IC_8$ = REF-02 (PMI).
$IC_9$ = UDN2580A of UDN2585A (Sprague or Texas Instruments).
$IC_{10}$ = ULN2803A (Sprague or Texas Instruments).
$IC_{11}$ = 1458

Miscellaneous:
$X_1$ = quartz crystal 11.0592 MHz.
2 off IDC connectors (for $K_1$ and $K_2$).
$K_1$ = PCB-mount header: 2 rows of 20 contacts (pitch: 2.54 mm).
$K_2$ = gold-plated PCB-mount header: 2 rows of 15 contacts (pitch: 2.54 mm).
PCB Type 880016-1 (see Readers Services page).

16

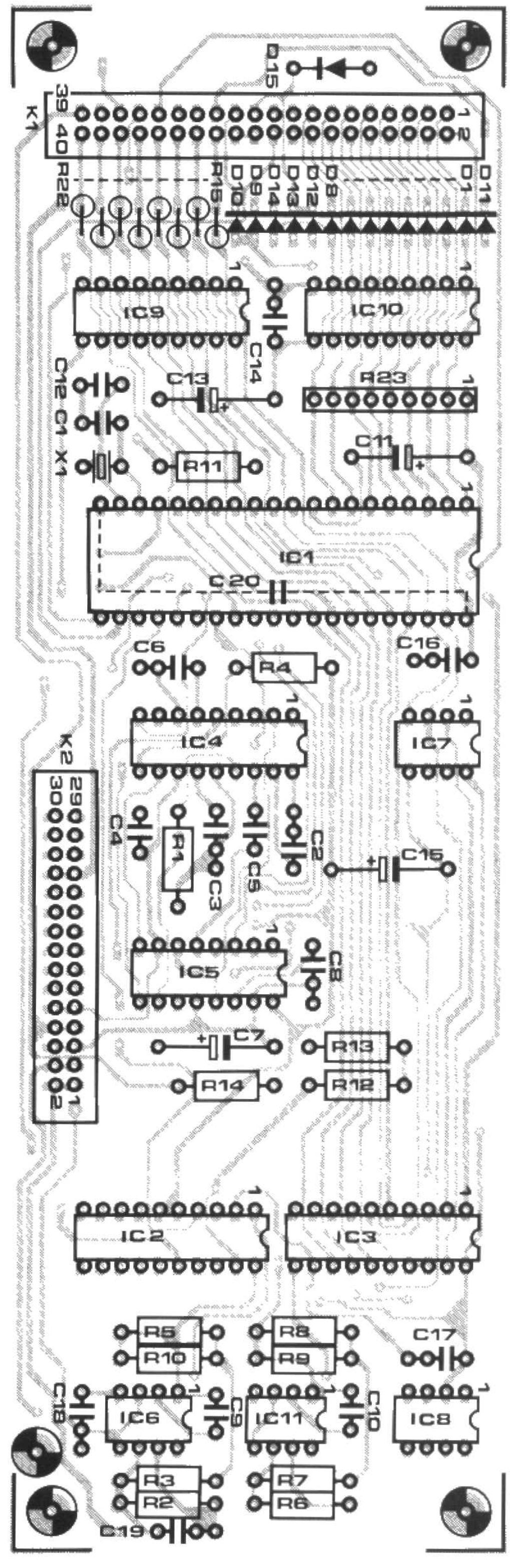


**Fig. 16. Component overlay of the double-sided, through-plated processor board.**

When key 1, 2 or 3 is pressed, the associated LED should light for a couple of seconds. The value shown on the displays is irrelevant, however, because the SEEPROM is not yet fitted. Now check control voltage $U_{set\,I}$. Connect a voltmeter to pin 3 or 4 of $K_1$ on the control board (or to pin 3 of $IC_2$ on the same board). Connect the meter ground to $+U_P$. Press U/I below SETTING (LED I should light), and turn SETTING clockwise. The value shown on the current read-out should increase to 2.5 A, while the reading taken with the

voltmeter increases to about 1.25 V. If this checks out, $IC_3$, $IC_{11}$ and associated components on the processor board can safely be assumed to operate correctly. Finally, A-D converter $IC_4$ may run relatively warm under normal conditions.

## Towards completion

When a 2×18 V; 3.3 A transformer is used, the maximum output current of the supply remains limited to 2 A. The microcontroller should be informed of this by fitting $D_{15}$. The SEEPROM should still not be fitted.

A 3¾-digit DMM is a must for setting up the power supply, since the resolution of the measurement then corresponds to that of the 12-bit D-A converter.

Commence setting up with the offset adjustment of the two opamps in the analogue circuit. Remove $IC_2$, and connect a voltmeter to the output of the supply, which is set to 0 V OUT. Preset $P_3$ is first turned fully clockwise, and then adjusted to the point from where the output voltage hardly decreases any further. The offset of the current adjustment circuit is compensated likewise. Mount $IC_2$, then remove $IC_1$. Set the supply to 1 V, 0 A out. Connect the ammeter (DMM) to the supply output, and adjust $P_4$ as $P_3$ until offset hardly decreases further. When offset can not be nulled properly, it may be necesary to use a type LF412A opamp for $A_3$ and $A_4$ (circuit diagram: Fig. 6).

The next step in the adjustment of the supply is setting $U_{set\,U}$. Switch the voltmeter at the output of the supply to the range closest to 30 V. Set the supply output voltage to a value just below the full-scale indication of the DVM. Set the output current limit to 100 mA. Fit a 10 kΩ potentiometer instead of $R_5$ (Fig. 6), and adjust it until the measured output voltage corresponds to the set output voltage. Remove the potentiometer, measure its resistance, and approximate this value as accurately as possible with one or more 1% metal-film resistors. The stability of the supply is impaired when a preset is used instead of metal-film resistors in position $R_5$. The measured voltage indicated by the supply is corrected by adjusting $P_2$ (Fig. 2).

Setting $U_{set\,I}$ is similar to the above procedure for $U_{set\,U}$. Temporarily replace $R_8$ with a 4.7 kΩ potentiometer. Set the supply for an output current between 1 and 2 A at an output voltage of 5 V. The value measured by the microcontroller is adjusted with $P_1$ (Fig. 2).

This completes the adjustment of the power supply, and it is, at long last, time to mount the SEEPROM and the front panel foil. The latter will almost always be slightly too large, so that it will have to be cut to size with the aid of a ruler and a sharp knife.

17

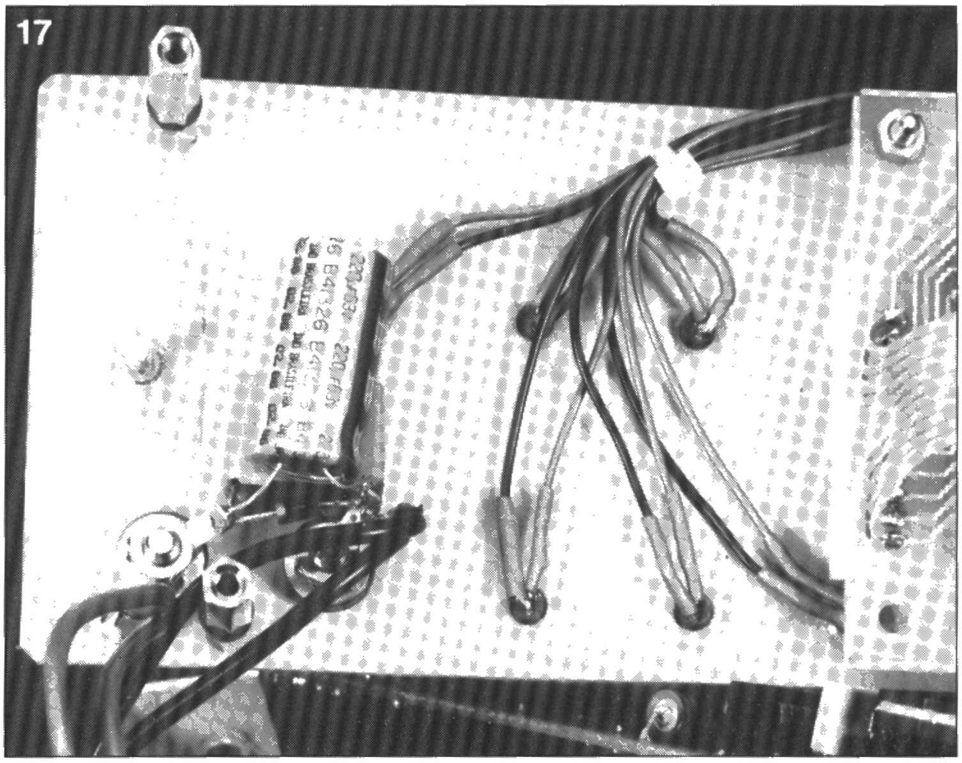

**Fig. 17. Two pairs of wires and a number of components are connected direct on the supply's output terminals.**

## Final remarks

Depending on the manner in which it is wired, the supply may have a tendency to oscillate. When oscillation is suspected or noticed, $C_{17}$ on the control board may have to be slightly increased.

When drivers Type UDN2885A are used, it is recommended to increase $R_{15}$. . . $R_{22}$ incl. to 22 Ω or 27 Ω in view of the lower saturation voltage of these ICs with respect to the UDN2580A.

The supply must be fitted in a sturdy metal enclosure to prevent stray radiation of the digital circuits. The enclosure is connected to earth (mains earth in the UK), **not** to the circuit ground, as close as possible to the mains entrance socket. $C_{26}$ is fitted well-insulated direct onto the mains switch (transformer side).

Figure 18 shows a detailed view of the component configuration at the supply output. The dashed line and the arrow to the right of $D_7$ have nothing to do with the third terminal of the temperature sensor. This terminal is cut off before mounting the device onto the same heatsink as $T_4$ and $T_5$. Also note the addition of a 100 nF; 400 VDC capacitor: it connects ground terminal $+U_s$ to earth for alternating voltages, and so reduces interference.

*PTh*

*Part 3 of this article will discuss the use of the serial interface on the power supply.*

**Note:** although you may buy the Type 8751 microcontroller from your usual Intel distributor, it can be programmed ONLY in our Design Department. This means that you have to send the device to us for programming. Do not forget to include a self-addressed, stamped return envelope (overseas readers: SAE and 3 IRCs). THE DEVICE CANNOT BE COPIED OR READ OUT!
Alternatively, you may, of course, order the ready-programmed controller direct from us through our normal Readers Services at £47.50 excl. VAT.

18

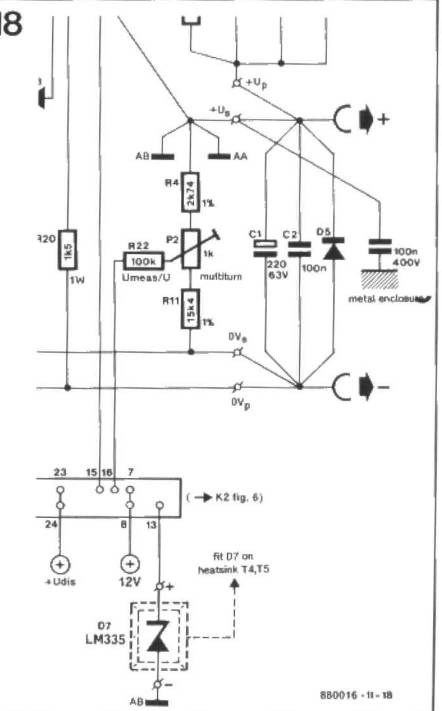


**Fig. 18. An addition to Fig. 2 in Part 1 of this article.**

**Component availability**

Availability of less common parts for this project was checked using the latest catalogues and stock lists of retailers and distributors. No guarantee is given for actual availability on a one-off basis. Companies whose address is not given are regular advertisers in this magazine. Sources given are not exclusive.

Semiconductors:

- B80C1500: Cricklewood; U.S.D.
- B80C5000: U.S.D.
- BS170: Cricklewood.
- 4N25: Cricklewood, U.S.D.; Maplin.
- TIP142: Cricklewood; U.S.D.
- MV57164: General Instrument U.K. Ltd. • Times House • Station Approach • RUISLIP HA4 8LE. Telephone: (08956) 36522. Telex: 23272. U.K. distributors are listed in InfoCard 504 (*EE* March 1987).
- NMC9306: National Semiconductor Limited. Electromail stock no. 301-656.
- HD11070: U.S.D.; ElectroValue Limited • 28 St Judes Road • Englefield Green • Egham • Surrey TW20 0HB. Telephone: (0784) 33603. Telex: 264475. Northern branch: 680 Burnage Lane • Manchester M19 1NA. Telephone: (061 432) 4945.
- PM-7548, REF-02: Precision Monolithics Incorporated. U.K. distributors are listed on InfoCard 508 (*EE* May 1987).
- DAC0831: National Semiconductor Limited • 301 Harpur Centre • Home Lane • BEDFORD MK40 1TR. U.K. distributors are listed on InfoCard 507 (*EE* April 1987).
- TL501: Texas Instruments; U.S.D.
- UDN-2580A: Cricklewood. Sprague distributors are listed on InfoCard 510 (*EE* June 1987).
- ULN-2803: Sprague; Electromail; U.S.D.

*Note:* U.S.D. = Universal Semiconductor Devices Limited.

Miscellaneous:

- Contact encoder: Bourns Electronics Limited • Hodford House • 17/27 High Street • HOUNSLOW TW3 1TE. Telephone: (01 572) 6531. Telex: 264485.
- Mains switch 1852.1102: Marquardt GmbH • D7207 Rietheim-Weilheim • West-Germany. Tel. (07424) 707-0. Telex: 760412 marq d.
- Relay: Siemens card relay V23127-B0001-A101 (preferred product). Siemens distributors are listed on Infocard 509 (*EE* May 1987).
- Power resistors: Dale A.C.I. Components Limited • 57A High Street • HEMEL HEMPSTEAD HP1 3AF. Telephone: (0442) 212991. Telex: 82402.
- Toroid transformer: Type 5C677 (240 V primary) or 5C517 (220 V primary). These transformers are produced specially for this project by ILP. The 240 V type is available from Jaytee Electronic Services.
- Heat-sink: Fischer SK85/50 mm. U.K. distributor is Dau Components • 70-74 Barnham Road • West Sussex TO22 0ES. Telephone: (0243) 553031.
- Quartz crystal: 11.0592 MHz. C-I Electronics • P.O. Box 22089 • 6360 AB Nuth • The Netherlands.
- Connector 7583: Molex Incorporated. Molex Electronics Limited • 1 Holder road • Aldershot • Hants GU12 4RH. Telephone: (0252) 313131.
- Enclosure: Retex Octobase RO.822. Imhof Bedco Standard Products Limited • Uxbridge. Telephone: (0895) 37123.

Or: Krieg Type KG5 (1000-172-000). Krieg Elektronik Gehäusebau GmbH • 5138 Heinsberg-Oberbrüch • West Germany. Telephone: +49 (2452) 6006/7/8. Telex: 832134.

# PEOPLE

## Prof. Barry Plumb to Plymouth Polytechnic

Three industry-sponsored chairs have been established at Plymouth Polytechnic: the Plessey Chair in Electronic Engineering; the Brymon Chair of Transport; and the Company of Designers Chair of Architecture.

**Prof. Barry Plumb** has been appointed to the Plessey Chair, which is combined with the post of Head of Department of Electrical and Electronic Engineering.

Prof. Plumb joins Plymouth Polytechnic from Sheffield City Polytechnica, where he was Head of Electrical and Electronic Engineering. He had previously worked as Design Engineer at Integrated Circuit Corporation, Phoenix, Arizona. Before that, he worked at Elliots (now GEC Avionics) on avionic control systems, and at Research Laboratories on optical data transmission systems.

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**Keith A. Bailey**, Chairman and Managing Director of BSA Tools, Birmingham, has been elected President of the Machine Tool Trades Association.

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**Mr Bill Ritchie**, a British Telecom research engineer, whose ideas were vital to the development of a worldleading switched-star cable television network, has been awarded the Martlesham Medal.

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Dataquest has appointed **Philip Daney de Marcillac** as Director of its newly formed European Computer Group. Previously European Research Director with the International Data Corporation, de Marcillac will also head up Dataquest's European Computer Industry Service (ECIS). This provides deep analyses of the use of computers in business and technical applications in the West European market.

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## Avantek appointments

Avantek Inc. has announced the following appointments: **Steven J. Allan**, Vice President and Corporate Controller; **Richard J. Clark**, Vice President, Telecommunications Division: **Robert M. Malbon**, Vice President GaAs Technology Development; **Peter L. Manno**, Vice President, Microwave Product Sales; **David A. Norbury**, Vice President, Sub-assemblies Division; and **Dr. James L. Vorhaus**, an acknowledged expert in the design, development, and production of GaAs FETs, Technical Program Manager, Power Projects.

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## Kokinakis for Microchip

**Kenneth 'Kip' Kokinakis** has been appointed as Vice President, Sales, by Microchip Technology Inc. (formerly General Instrument Microelectronics).

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Arrow Hart (Europe), the Plymouth-based manufacturer of electrical switches, has appointed Yvonne Squire as Marketing Services Controller.

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**Vincent Nicholas** has been appointed as Materials Manager by Radamec Microsystems and will be responsible for all materials and components purchases.

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**Graham Marshall** has been appointed sales engineer with responsibility for the Avel engineering advisory service where he will assist customers to select the most suitable type of emergency power supply.

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# ELECTROSTATIC PAPERHOLDER

**Photographers, draughtsmen, compositors, lithographers, artistic as well as technical designers, and, of course, architects use drafting tables which should allow quick and safe exchanging, positioning and fixing of large sheets of paper. For this purpose, an electrostatic paperholder has significant advantages over clip-on systems or bits of drafting tape.**

A wide range of equipment is currently available for putting graphics information on paper. Such equipment includes printers, plotters, X-Y and X-t recorders. In all of these, it is essential that a pen device or printer head can move with respect to the paper surface. In most cases, paper is held on a roll, which is rotated to achieve movement in the Y-direction, while a carriage is used to achieve movement of the roll, or the pen, in the X-direction. There are, however, also systems in which the paper is held flat and secured on the working table, while the pen is moved across it in both directions. This arrangement is essentially identical to that of the well-known drafting table, for which the electrostatic paperholder was developed about 20 years ago. The current trend in plotter design, however, is clearly towards the rotating paper roll.
To prevent the electrostatic paperholder falling into oblivion, this article aims at providing essential information on the operation, designing and building of this drafting aid.

## Theory of operation

The general structure of the electrostatic paperholder is shown diagrammatically in Fig. 1. In principle, the construction is relatively simple, but some theoretical knowledge is required for explaining and understanding the basic operation and the effect of all parameters involved.

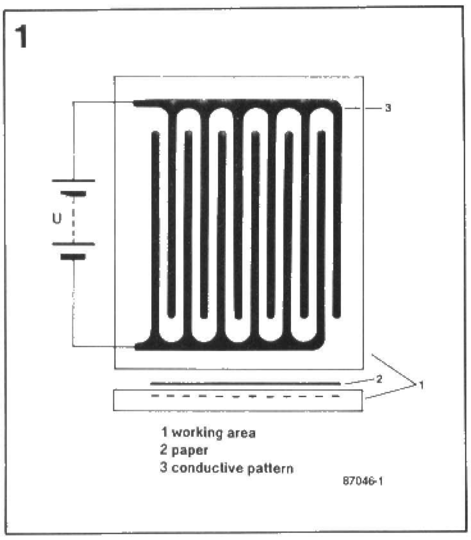


**Fig. 1. Basic structure of the electrostatic paperholder.**

The system can be analyzed in two ways. One is based on the theory of electrical fields. This includes the possible, but important, role of a large number of side-effects that other models fail to take into account.
The second way of analyzing the electrostatic paperholder is an essentially qualitative approach which has the advantage of being more illustrative and better comprehensible than the theory of electrical fields.
Figure 2 shows a schematic representation of a part of the electrostatic paperholder. The diagram shows voltage $U$ present between two tracks of the conductive pattern. This voltage causes an electric field, $E$, between the tracks. The field strength is directly proportional to the voltage applied. Lines of force will cross the working area, but also extend beyond this, traversing the paper sheet. This will result in a certain degree of polarization of the paper due to dielectrical shift, which, in turn, is explained by the relative permittivity of paper, which is about 3 ($\varepsilon_r$ = dielectric constant).
The force between paper and working table is then best understood in terms of a force between two charges: one is the apparent charge caused by polarization of the paper (proportional to field strength $E$ and, therefore, voltage $U$), the other the charge on the electrodes of the working table (also proportional to $U$, and, in addition, to the capacitance). Since voltage $U$ determines both the degree of paper polarization and the amount of charge on the electrodes, it can be safely assumed that the force is proportional to the square of $U$. In addition, the force between two charges is inversely proportional to the square of the distance, which means that the thickness of the insulating layer above the electrodes is an important factor. Also note that the number of lines of force traversing the paper decreases with an increase in the distance between paper and electrodes.

The above model allows simple deducing of a number of additional parameters that determine the adhesive force between paper and working table.
Relative humidity of the paper is an important parameter. Relative permittivity of water is as high as 70, caused by the dipole moments of individual water molecules. As a result, dielectrical shift in paper with high relative humidity will be considerable, causing increased adhesive force. It should be noted, however, that humid paper has conductive properties, which are augmented by impurities in water. Since electric field strength is effectively cancelled in a conductor, there will be no force at all on the paper when this is humid. In practice, it has evolved that a relative humidity of 40-50% is optimum for most applications.

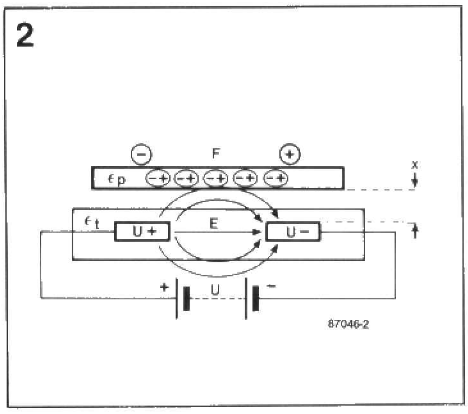


**Fig. 2. The electric field causes dielectric shift in the paper, resulting in a force between paper and electrodes.**

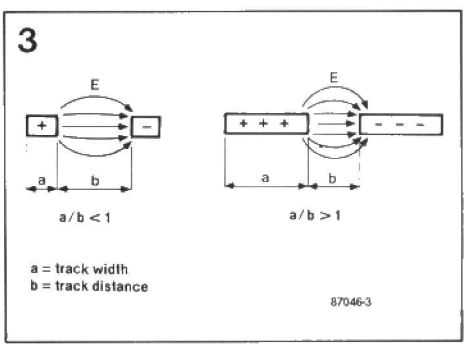


**Fig. 3. The pattern of the lines of force is determined by the geometry of the track pattern.**

A further important parameter to consider is the geometery of the electrode pattern, since this determines the pattern of the lines of force. Tracks whose width is small relative to the track-to-track distance cause the field to become so narrow that it does not act on the paper. A higher width/distance ratio gives a more favourable pattern of the lines of force (see Fig. 3). A ratio of slightly more than 2 was found to give best results in practice.

The final parameter to consider is the permittivity of the working table material. High relative permittivity results in high inter-electrode capacitance and, therefore, a high amount of electrode charge ($Q=UC$). Hence, adhesive force is also greater.

The curves in the graph of Fig. 4 were obtained from experiments. The y-axis shows force per unit of area at a certain voltage and electrode distance. Increasing this distance results in strong vertical shrinking of the curves. Increasing the voltage by a certain factor compresses the vertical scale with the square of the factor.

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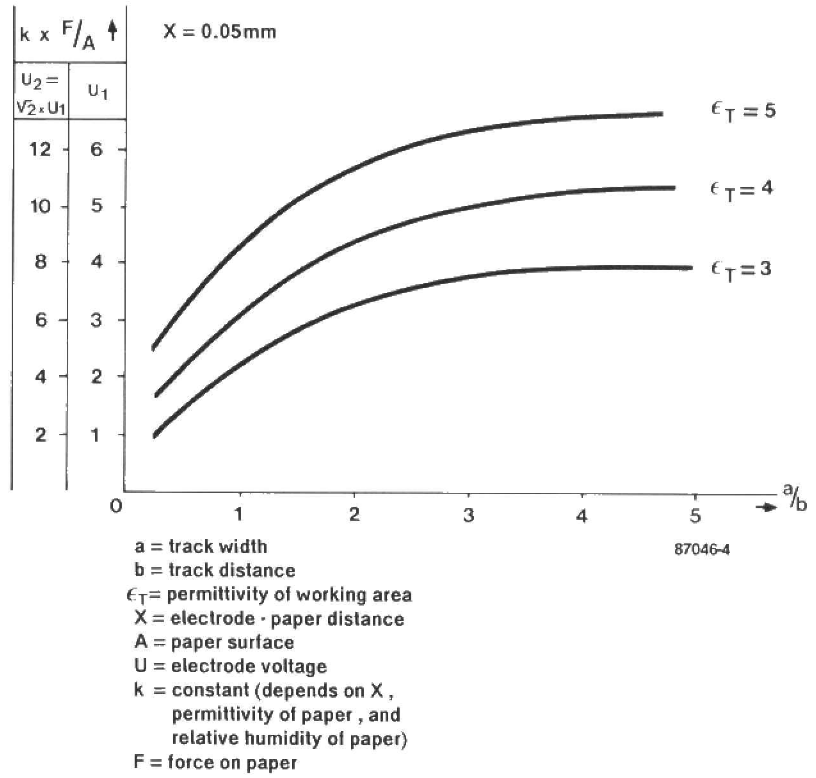


**Fig. 4. Force per unit of area as a function of the ratio of track thickness to track distance, with relative permittivity of the working area as a parameter. Force is a square function of the voltage.**

## An experiment

Observing the above criteria, the following conditions should be met for obtaining reasonable adhesive force on the paper:

- Voltage should be as high as possible without causing arcing between tracks.
- Paper-electrode distance should be as small as possible.
- Relative permittivity of the working table should be high.
- Ratio of track width to track distance should be greater than 2.

A further important consideration not mentioned so far is safety. Clearly, the first two of the above conditions conflict in respect of safety. For an efficiently operating paperholder, paper-electrode distance should be of the order of hundredths of a millimeter, or one tenth at the most. A voltage of 1 kV already requires special properties of the upper layer of the working table in respect of insulation. Standard epoxy PCB material is unsuitable here because it is too thick. Considerable adhesive force is obtained when the paper is laid direct onto the copper tracks, but audible corona effects via the paper will be observed ($U=2.5$ kV; track distance: 2.5 mm). Polycarbonate foil as used for *Elektor Electronics* adhesive front panels ensures sufficient electrical insulation, but has the disadvantage of reducing the electrostatic effect by increasing the electrode-paper distance. Better results should be obtainable with much thinner foil as used for covering model airplanes. This material is simple to secure on surfaces with the aid of a flatiron, but the insulating properties would have to be checked in practice.

## Practical suggestions

The drawing of Fig. 5 shows a suggested structure of an electrostatic paperholder. Ordinary PC board material can be used as the base material. The track pattern is readily made with the aid of rub-off artwork transfers. A complete raster pattern on one sheet (track width: 3 mm; track distance: 1.5 mm) is rubbed off in one go. Alternate tracks are then shortened, and protruding tracks are connected at both sides. After etching, the panel can be smoothed with a thin layer of potting compound (car body repair material is suitable here). After this has stiffened, the layer is cleaned, polished, and covered in model aircraft foil (Fig. 5).

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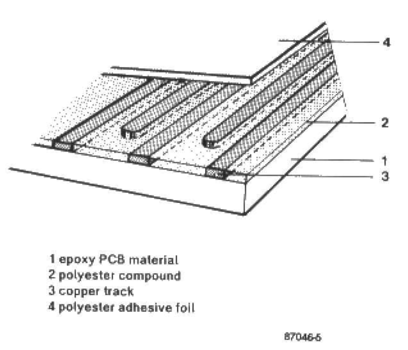



**Fig. 5. Structure of a home-made paperholder to traditional design.**

The high voltage source for the paperholder need not supply current because leakage current in the etched panel will be negligible. Figure 6 shows a suggested circuit for the high voltage cascade. The use of a mains transformer is obligatory. If a 1:1 safety transformer is not available, a step-down type (240 V/117 V) may be used with the corresponding number of cascade sections added. The actual voltage required depends largely on the foil thickness, so that the high voltage source is best constructed in a step by step manner by adding as many cascade sections as required. Commercially available electrostatic paperholders usually operate at 1 kV.

A prototype of the paperholder required 2...3 kV (track width 3 mm; track distance 1.5 mm; foil thickness approx. 0.05 mm). The circuit diagram of the voltage source used is shown in Fig. 6. Four cascade sections in each arm were

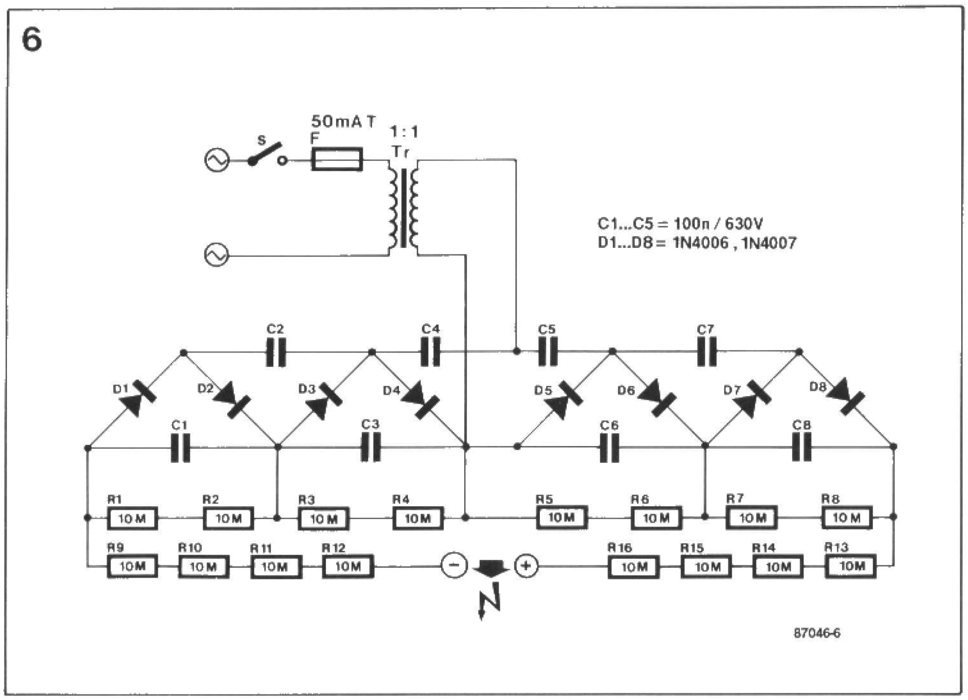



Fig. 6. **Symmetrical high voltage supply for the paperholder.**

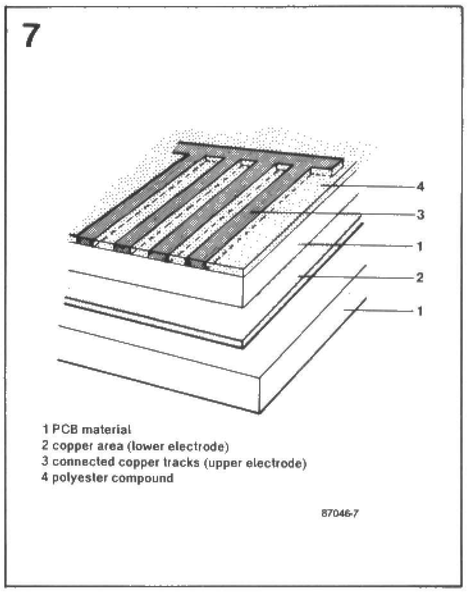



**Fig. 7. Alternative construction of a paperholder, which is esentially a PCB sandwich. The HV electrode is formed by the unetched copper surface on the lower circuit board. The upper electrode is earthed.**

used to give an output of 8×330 V=2640 V. The resistors fitted in parallel with the high-voltage capacitors ensure that the paper is released within 2 to 3 seconds after switching off. The high-value series resistors function as current limiters to safeguard users from lethal currents when the electrodes are accidentally touched. Every precaution should be taken to prevent this happening, bearing in mind that even small currents can be lethal when carried in or near the heart area.

## An alternative

The electrostatic effect of the previously suggested paperholder is still relatively small, notably when using certain types of photographically sensitive or other PVC-based paper. An alternative paperholder was, therefore, designed and studied to overcome this defiency. The new structure is shown in Fig. 7: the working surface is essentially composed of double-sided PCB material. It is, however, recommended to use two separate sheets of single-sided material, since this automatically ensures insulation of the lower side. The lower electrode is simply a large conductive surface. The top side carries a fine pattern of interconnected tracks (a checkered pattern is also suitable) which forms the complementary electrode. Paper laid on the top surface will be at the potential of the upper electrode. The function of the etched pattern is to ensure that force is evenly distributed over the entire sheet. Adhesion is not obtained by dielectric shift in the paper, but as a result of the force between the charge transferred onto the paper by the upper electrode, and the charge on the lower electrode. There is no dielectric shift in the paper because this lies in an area of one potential only. This set-up has advantages in respect of safety and construction, because the upper electrode can be connected to earth, while the high voltage is only present well-insulated at the lower side.

The circuit diagram of Fig. 8 shows that the cascade used for the alternative paperholder is asymmetrical to prevent high voltages between the primary and secondary winding of the transformer. A 5-stage HV cascade was used to obtain an output of about 1700 V. Figure 8 also shows the use of two small low-voltage transformers whose secondary windings are connected to act as a 1:1 safety transformer.

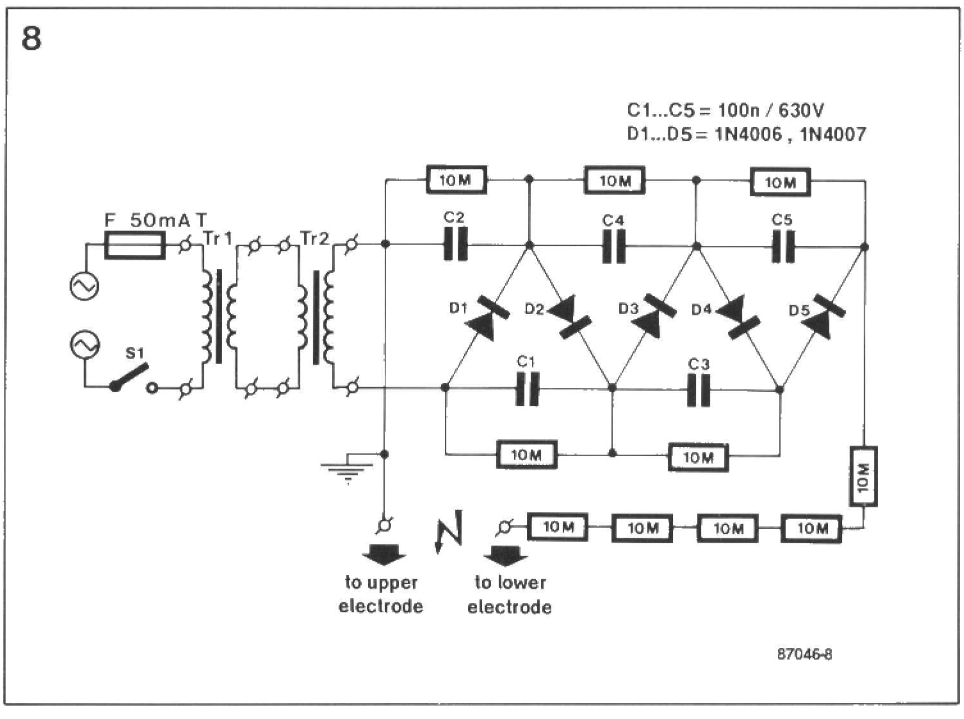


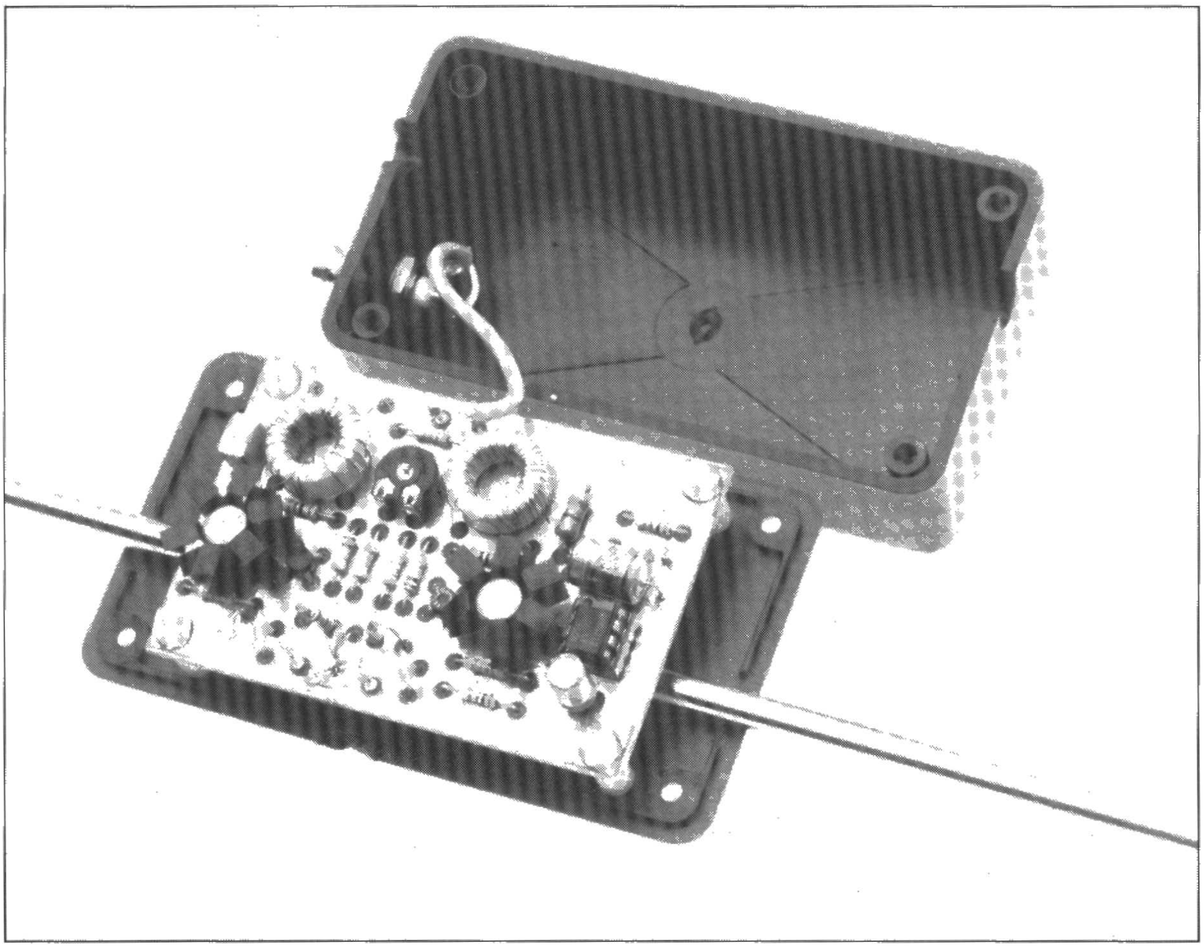

**Fig. 8. Suggested HV source for the alternative paperholder. $U_{out}$ is approximately 1700 VDC at an input of 240 VAC.**

A disadvantage of the alternative paperholder described is the need for the paper to be in galvanic contact with the upper electrode. This means a higher risk of oxidation of the copper tracks, unless these are tinned. The upper side of the work area can be smoothed with a thin layer of potting compound as discussed earlier.

It is hoped that this article provides a basis for further experiments in building an electrostatic paperholder of the required size. Your practical notes and comments are appreciated!

*TW*

# WIDEBAND ACTIVE AERIAL FOR SHORTWAVE RECEIVERS



Are you among the many SW DXers that lack space or financial means to erect a high aerial tower in the back garden? Or do your neighbours object to your hanging up a long wire?
Here is a compact, high-quality, balanced preamplifier that works with a shortened dipole or quad-loop aerial. The design is inexpensive and simple to build, yet couples good noise suppression to high sensitivity and immunity to cross-modulation.

It is generally known that interference is severe on practically all shortwave bands (1.6 — 30 MHz). This situation is not likely to improve in the near future in view of ever increasing man-made noise, and the tendency of owners or operators of shortwave broadcast and utility stations to use excessive output powers for political and commercial reasons. Every shortwave DXer will at some time have found that high signal levels on nearby channels give rise to cross-modulation and blocking effects in the receiver if this has poorly designed RF sections which, consequently, can not handle large signals very well. Man-made interference can be kept to a minimum by installing the aerial out of doors, and connecting it to the receiver input by means of a shielded (coaxial) or a balanced cable (twin feed).

The aerial booster presented here has a balanced input suitable for connection to a wide range of loop, quad-loop or dipole aerials. It should be connected direct to the aerial terminals (feed points), and supplies the amplified RF band to the shortwave receiver via a length of coaxial cable, which also carries the supply voltage.

## Aerials combat interference

There are a number of possibilities of improving reception below 30 MHz by reducing the level of interference. Some aerial systems are based on suppression of the electrical component in received signals. Radio signals are composed of a magnetic and an electric component, which are at right angles. In general, man-made interference, such as that radiated by mains lines in and around the home, is mainly composed of electrical components. The operating principle of the ferrite rod is based on the balance between the magnetic and electric component in radio signals. Thanks to the special ferromagnetic properties of the rod, it is highly insensitive to electric components, hence aids in keeping interference to an acceptable level. Unfortunately, however, the ferrite aerial is unable to reduce interference caused by strong magnetic fields generated by deflection yokes in TV sets. Fast pulse transients and high currents in these inductors give rise to interference over a wide frequency range in the form of line oscillator harmonics occurring at 15,625 Hz intervals. Fortunately, the radiation pattern of the ferrite aerial has an eight-like shape, so that line frequency inter-

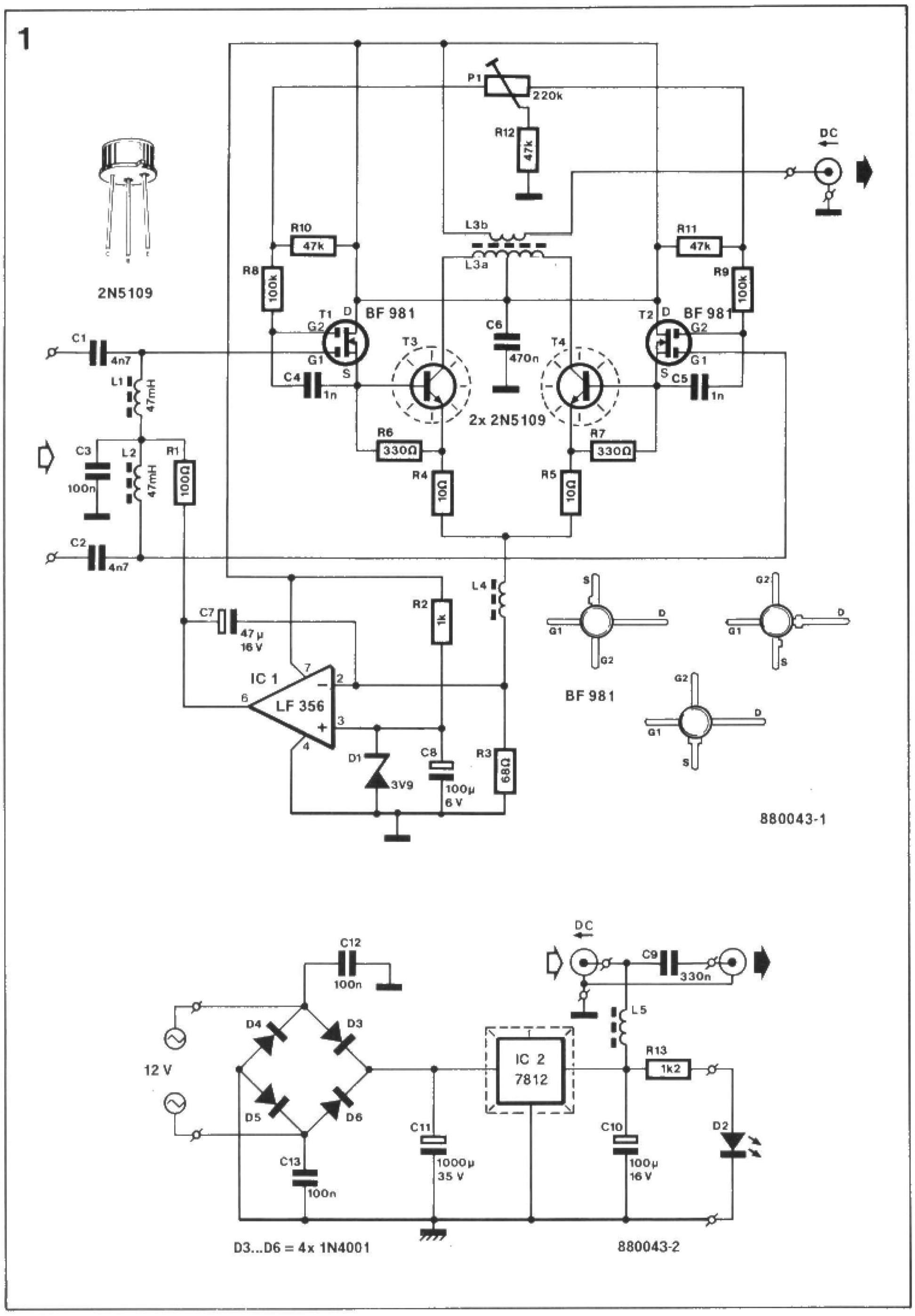



**Fig. 1. Circuit diagram of the active aerial and associated power supply.**

ference can be reduced to some extent by rotating the the rod in the horizontal plane.

Another type of aerial that gives good results on the SW bands is the loop or quad loop aerial, whose behaviour is largely similar to that of the ferrite rod. One advantage of the the loop aerial is that it can be relatively large, resulting in higher sensitivity than the ferrite rod. Like the ferrite aerial, the loop is essentially an inductor, bearing in mind that it is one without a core whose ferromagnetic properties pose restrictions on the usable frequency range.
Immunity of the loop and the ferrite aerial to very strong electric fields can be enhanced by encapsulating the aerial in a non-ferrite metal. This forms an electric shield to prevent the conection wires of the ferrite aerial, or the wire loops of the loop aerial, picking up electric fields. Care should be taken, however, to avoid the encapsulation forming a short-circuited winding, since this would cause magnetic components in the radio signal to be lost altogether. When used, the screening should, therefore, have a gap, with each of the halves separately connected to earth.

A properly dimensioned, installed and terminated dipole aerial is also relatively insensitive to electrical interference. Although the dipole is mainly sensitive to the electric component in radio signals — notably when lack of space forces the actual size to be made smaller than the conventional half wave length — this type of aerial has the advantage of being balanced. The ideal dipole responds only to signal differences that exist between its two identical poles. The dipole is a balanced aerial and must, therefore, be connected to a balanced cable and amplifier input. An unbalanced cable almost invariably results in improper termination, while it may also change the radiation pattern because it functions as an extension of one of the dipole elements.

## Circuit description

The circuit diagram of the balanced wideband preamplifier plus remote power supply is given in Fig. 1. The amplifier inputs must be connected *direct* to the feeder points of the dipole or loop aerial. With this in mind, it should be fairly obvious why the circuit is powered via the 50...75 Ω downlead coax cable connected to the supply, which is installed near the receiver in the home. Input impedance of the preamplifier is relatively high to enable correct termination of a much shortened dipole. Signals from the dipole elements are capacitively fed to the gate-1 terminals of dual-gate MOSFETs $T_1$ and $T_2$. The gates are held at the correct direct voltage via chokes $L_1$ and $L_2$. The drains of the MOSFETs are commoned and decoupled for RF signals by $C_6$. The RF signals available on the source terminals are raised in medium-power transistors $T_3$ and $T_4$, which form a push-pull output stage feeding impedance transformer $L_3$. Opamp $IC_1$ ensures that the amplifier is fed with a constant current. This is important because $T_3$ and $T_4$ must operate within the linear range of their characteristics. The current through $T_3$ and $T_4$ may be reduced slightly by increasing the value of $R_3$. This is only recommended, however, to constructors fortunate enough to live in an area where field strength in the SW bands is not so high as to cause cross-modulation in the receiver.
The input of the preamplifier may be connected to a loop aerial with a parallel capacitor. This effectively limits the usable frequency range, but increases sensitivity because of the resonance effect. It should be noted that any screening of the loop as discussed above may considerably change the tuning range of a variable capacitor connected across the loop feeder points. Also, the Q (quality) factor of the aerial plus tuning capacitor may be reduced, which in turn results in a smaller output signal.

Although it has, strictly speaking, nothing to do with the preamplifier discussed here, it may be interesting to experiment with a combination of a vertical dipole (electric component) and a loop or ferrite rod (magnetic component), each with its own preamplifier. Provided it is ensured that the signals supplied by each preamplifier are of

equal amplitude when they are fed to the receiver input, this arrangement should enable directional reception in the long and medium wave bands, thereby offering the possibility to blank out strong unwanted signals by appropriate positioning of the aerial combination.

The power supply for the masthead-mounted preamplifier is of conventional design, and requires no further discussion other than that it is preferably fed from a 12 V (AC or DC) mains adapter.

## Construction and adjustment

Commence the construction of the preamplifier with winding the inductors (use 0.2 to 0.3 mm dia. enamelled copper wire):
$L_{3a}$ = 10+10 turns (centre tapped) on ferrite ring core Type G2.3-FT16 or T82-47;
$L_{3b}$ = 4 turns on above ferrite ring;
$L_4$ and $L_5$ = 30 turns on ferrite ring as above.

The printed circuit board for the active aerial is shown in Fig. 2, that for the power supply in Fig. 3. Construction is straightforward, and requires no further detailing. Keep the terminals of the dual-gate MOSFETs short-circuited with thin wire while handling, mounting and soldering these static-sensitive devices (they are claimed to have built-in protection networks, but it is better to be safe than sorry). Surface mount capacitors $C_4$ ands $C_5$ are soldered direct on to the gate-2 and source terminals of $T_1$ and $T_2$.

Adjustment of the active aerial is fairly simple, and can be done in the

**Parts list**

PREAMPLIFIER BOARD

Resistors (±5%):

R1 = 100R
R2 = 1K0
R3 = 68R; 0.25 W
R4;R5 = 10R
R6;R7 = 330R
R8;R9 = 100K
R10;R11;R12 = 47K
P1 = 250K preset H

Capacitors:

C1;C2 = 4n7
C3 = 100n
C4;C5 = 1n0 SMD
C6 = 470n
C7 = 47µ; 16 V; radial
C8 = 100µ; 6 V

Semiconductors:

D1 = zener diode 3V9; 400 mW
T1;T2 = BF981 (Bonex; Universal Semiconductor devices; C-I Electronics)
T3;T4 = 2N5109 (Motorola; Cricklewood)
IC1 = LF356

Inductors:

L1;L2 = 47mH . . . 100 mH radial choke (L1 and L2 must have the same value). Toko series 181LYxx3 (Cirkit; Bonex).
L3;L4 = see text. Wound on ferrite ring core G2.3-FT16 or T82-47 (MicroMetals/Amidon).

Miscellaneous:

PCB 8840043-1 (see Readers Services page).
Heat-sinks for T3;T4.

2

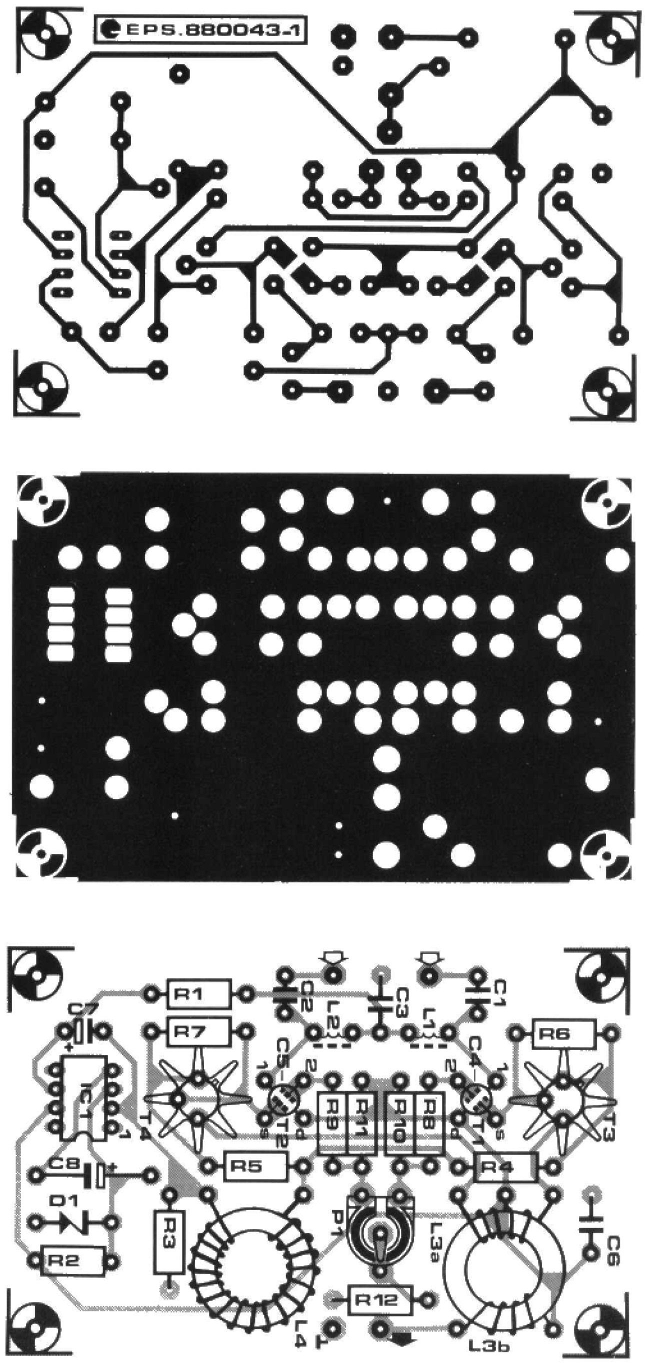
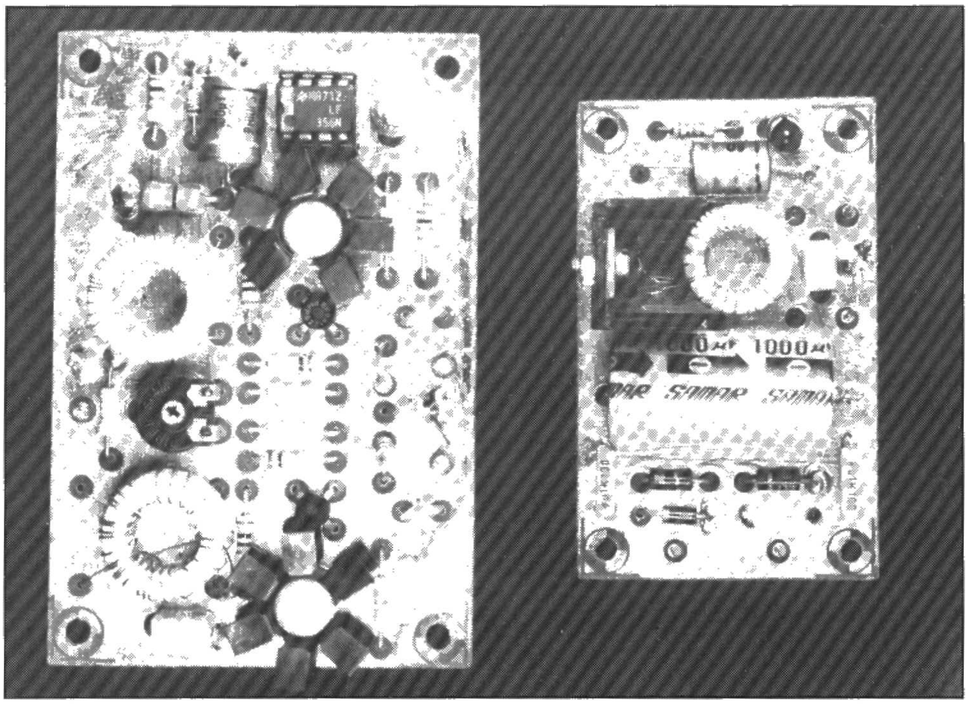



Fig. 2. Printed circuit board for the wideband preamplifier.



Completed prototypes of the preamplifier and supply board.

workshop, i.e., the circuit need not be installed in its final location. Connect a short wire aerial to $C_1$ or $C_2$. Tune the receiver to a relatively strong transmission, apply power to the circuit, and note the S-meter reading. Temporarily connect $C_1$ to $C_2$, so that the same aerial signal is applied to both preamplifier inputs. Ideally, the station should not be heard any more because the amplified signals are of complementary phase, cancelling each other in $L_3$. Balance the amplifier by carefully adjusting $P_1$ for the lowest S-meter reading on the receiver (switch off the AFC).

The completed preamplifier is, of course, mounted in a water-resistant enclosure — the photographs show a suggestion for this. Remember that large metal parts in the direct vicinity of the dipole, such as the aerial mast but also the coax cable, may upset the carefully arranged balance, and thus the operation, of the amplifier, resulting in much reduced performance.

*B*

**Reference:**
*Radio Communication Handbook*. Chapter 12: Aerials. Published by the Radio Society of Great Britain.

**Parts list**

POWER SUPPLY BOARD

Resistor (±5%):

$R_{13}$ = 1K2

Capacitors:

$C_9$ = 330n
$C_{10}$ = 100$\mu$; 16 V $C_{11}$ = 1000$\mu$; 35 V
$C_{12}$;$C_{13}$ = 100n

Semiconductors:

$D_2$ = red LED
$D_3$ . . $D_6$ incl. = 1N4001
$IC_2$ = 7812

Inductor:

$L_5$ = as $L_4$.

Miscellaneous:

Heat-sink for $IC_2$.
PCB 8840043-2 (see Readers Services page).

3

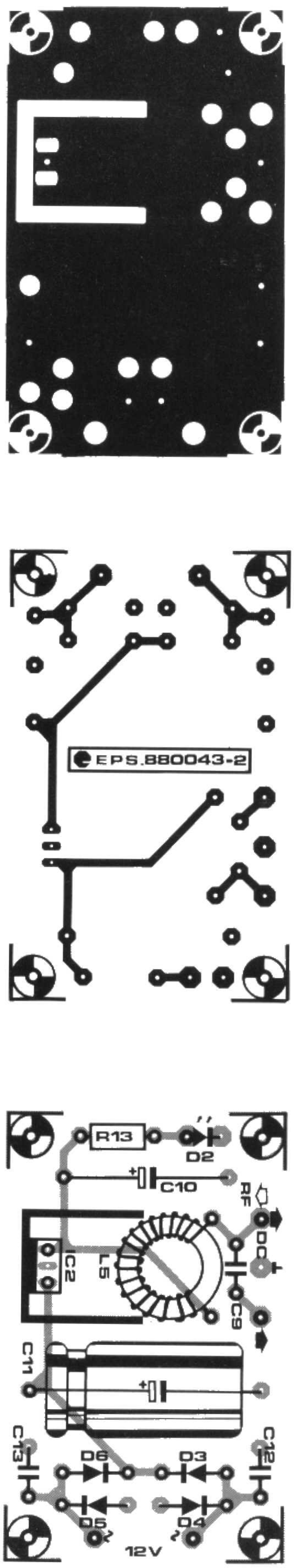



Fig. 3. Printed circuit board for the power supply.

# HOLOGRAPHY AND LASERS PRODUCE SUPER PRECISE MEASUREMENT

by Anthony St E. Cardew*

**Advances in the application of opto-electronics such as laser techniques and holography have brought industrial measurement to new realms of precision and speed. The ability to have workshop systems with inherent accuracies of a half wavelength of light has opened up a whole new vista. Also, developments in holography have extended its application to, for instance, use in the quality control of critical parts and the location of defects.**

In the United Kingdom, a significant advance in laser interferometer design has been the pioneering of a novel system by Michael Downs and Kenneth Rains of the National Physical Laboratory[1], which was exploited by Linear Instruments[2] and forms the basis of its LIL 3000 series of laser interferometers.

## Lower cost

Most laser interferometers use a sophisticated laser and electronic system to produce measurements and they are consequently very expensive. However, the laser transducers manufactured by Linear Instruments, which are of the remote interferometer type, achieve a performance equal to, or better than, conventional laser interferometers by using a simpler and less expensive method.

Instead of producing two identical signals with 90 degree phase difference, they produce three signals at 0, 90 and 180 degrees. By subtracting 0 from 90 and 90 from 180, the results are two signals with a phase difference of 90 degrees which switch about zero volts.

Apart from its simplicity and low cost, the great advantage of the system is that it is not dependent on any one laser but will operate with an unstabilized laser over short distances.

Although laser interferometers have a working range of 30 metres or more, this is dependent on the environment as the beam will move in turbulent air. Maintaining a good overlap between the reference beam and the measuring beam is essential and, therefore, over the longer ranges, it is better to use a larger beam diameter.

On the LIL series of laser heads it is possible to change the standard 3× beam expander to 5×, increasing the beam from 3 mm to 5 mm diameter.

## Errors eliminated

In practice, the interferometer is supplied with a two-mode stabilized laser. The LIL models, based on the National Physical Laboratory design, are becoming established round the world in the fields of measurement and positional control.

The range of calibration equipment has been complemented by a tripod-based laser and interferometer system known as Uni-Cal which is specifically designed as a portable, length-measuring system for machine calibration. It consists of a laser mounted on a heavy-duty tripod. As the retro-reflector moves backwards and forwards, the interferometer measures its position.

With a mirror, it is possible to reflect the interferometer beam on to another axis so that three axes of the machine can be calibrated from one position. While this technique can produce errors in conventional systems, the special 'dead path' facility in the Uni-Cal system software eliminates this problem.

The latest addition is a software package written specifically for the calibration of transducers and ballscrews which allows up to five runs of 1000 points to be processed to provide statistics and graphs. A special feature with this package is provision for a chart-driven X-Y plotter which will enable the scale of the X axis of the graph (the measured axis) to be varied to suit the requirements from a single A4 sheet to a 25 metre long chart.

## Shadow graph

The Beta Instrument Company[3] specializes in applying laser technology to the measurement of optical fibres, wires and filaments and also glass thickness.

Its most recent development is the enhanced Beta fast response fibre laser diameter gauge which provides a precise method of measuring optical fibres, fine wire drawing, wire/cable extrusion, and filament manufacture.

The unit operates on the principle of a fine laser beam sweeping past the product to be measured, which is located in the optical gate. The resultant signal is collected on a photocell, which produces a square wave that is related to the precise diameter of the profile being measured.

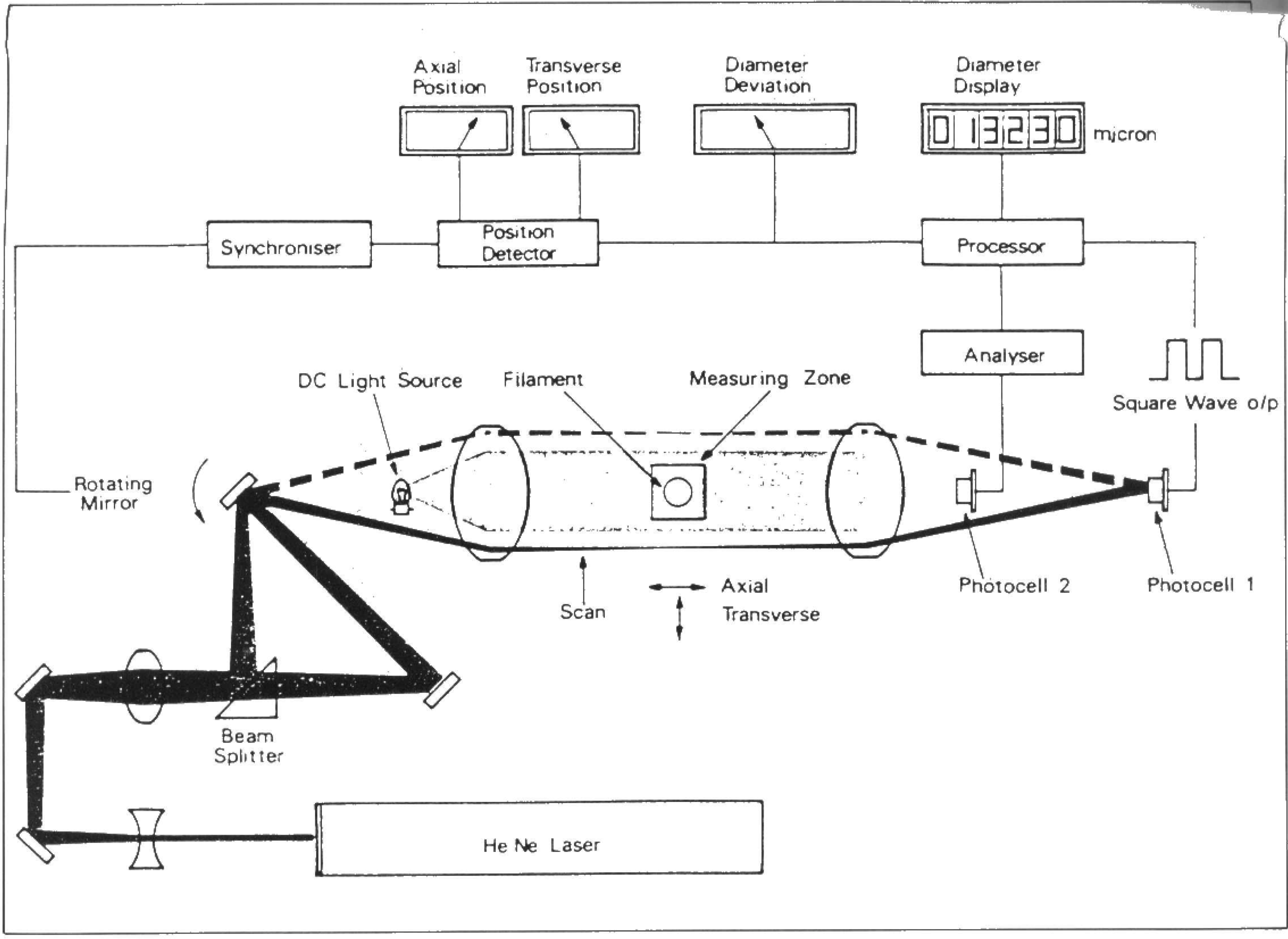
A second beam of light from a d.c.-operated continuous illumination source is projected on to the same product to produce a shadow graph image for examination of the surface imperfections and instant variations of the product under test.

This second beam of light is collected on a second photocell which produces a signal proportional to the instantaneous variations of the profile shadow of the product. The signals from the photocells are conditioned in the microprocessor which provides an actual and diameter deviation display.

## Measuring reflections

Another laser-based system developed by Beta is the glass thickness gauge used for non-contact measurement of wall thickness of glass tubes, bottles, phials, capillary tubes and so on, as well as glass

* Anthony St E. Cardew is chairman of the Metrology and Inspection Technical Group of the Institute of Quality Assurance.




**Principle of operation of the Beta SF fibre laser diameter gauge.**

plate. Measurement is made as the glass is produced from the furnace, hot or cold.

The general method relies on a laser beam being made to fall on the surface of the glass tube or plate being measured, and produce reflections from the two surfaces. Both reflections pass through a lens system and on to a diode array, which is being scanned at a rate of 100 times a second.

Each scan produces a measurement that is checked for credibility and, after processing, the actual thickness of the material is shown on a six-digit display. In the first instance, the reflective index of the material has to be dialled into the unit by the user.

Alternatively, if the exact thickness of the glass plate is known, the instrument can be used to determine the refractive index.

## Three dimensional data

For lower orders of accuracy, the Beamguide red-cross optical alignment system by Coteglade Photonics(4) provides a low-powered He-Ne laser system. An inexpensive, adaptable, general utility tool, it projects a visible laser line or cross-hair on to the target object, with finely adjustable accuracy to give precise planar positioning information.

Full orthogonal positioning accuracy can be obtained by mounting three Beamguides in suitable positions to give three-dimensional information. Typical applications include levelling in which a fixed, remote Beamguide gives precise positional orientation and levelling information for manned or automatic machinery.

It can also be used for centring where two or more beams can be focused on the central point of a piece of equipment whether static or moving.

Holography is finding increasing application in industry, particularly in the field of non-destructive testing where holographic interferometry enables small flaws or defects to be seen. In its simplest form, the process involves superimposing two holographic exposures on the same film and subjecting the object to mechanical or environmental changes between exposures.

## Aid to design

The reconstructed hologram shows the object overlaid with a fringe pattern (caused by the interference of the two exposures) which is effectively a topographical map with contours defining every change in the surface of the object.

The distance between each fringe represents a movement of half a wavelength of the laser illumination. If a He-Ne laser at 632.8 mm is used, for example, a change of 0.3 $\mu$m will be detected. Holographic inspection is useful not just for checking production items but also as an invaluable aid in their design and development.

An example of a commercial holographic system is the Ealing Electro-Optics(5) Vidispec electronic speckle interferometer, which is finding increasing application in non-destructive testing. It measures the surface displacement of an object subjected to a mechanical load or an environmental change.

This is achieved with an accuracy of about a wavelength of light and enables any flaws or defects in the material or design of a component to be identified quickly.

## Dual-size holograms

Unlike holographic non-destructive testing, Vidispec works well in daylight and artificial light and needs no film or special processing techniques.

The optical head houses a 10 mW He-Ne laser, a precision video camera, and all the necessary optical and mechanical

components to create and record a speckle pattern interferogram.

The electronic unit contains the video camera controls, digital frame store and electronic processing functions.

The Holocam model 70 camera from Ultrafine Technology[6] enables the user to make both 127 × 101 mm and 254 × 203 mm holograms from the one instrument. It incorporates an improved method for holding the film captive, using a single glass plate and a vacuum system. Recent applications include the testing of bonded structures.

## Optical system

A significant application of the laser-to-surface metrology is the National Physical Laboratory's development of an optical system for the measurement of surface profile. The system incorporates a laser and takes advantage of the very high measuring sensitivity of polarization interference microscopy.

The practical result is a surface profilometer with sub-nanometre sensitivity for the measurement of smooth surfaces.

The system uses a birefringent lens in conjunction with a microscope objective to provide a double-focus objective in which the two foci correspond to the light of orthogonal planes of polarization.

When the surface under examination is placed on one of the focal planes, the light of one polarization is reflected from an area equal to the resolution limit of the objective. The light of the other polarization, on the other hand, is out of focus and is reflected from a larger area.

Each beam integrates the level of the surface over the area from which it is reflected. The larger area provides a mean reference level which should remain fixed as the area is scanned.

## Double-focus objective

The two beams are combined in a polarizing interferometer and, as the surface is scanned, the variation in path difference between the focused and unfocused beams provides a measure of surface profile. An electro-optic system is employed with an electrical output directly proportional to this path difference.

The use of a common-path interferometer, in which both measurement level and the reference level are generated from the test surface, provides a measurement that is insensitive to movement in a direction perpendicular to the surface. Therefore, the use of this form of double-focus objective renders the system insensitive to tilt of the test table.

Patents for the system are held by the National Physical Laboratory and versions of the nano-profilometer are being manufactured by British Aerospace and the Cranfield Unit for Precision Engineering (CUPE), which is part of the Cranfield Institute of Technology.

**References.**

1. National Physical Laboratory, Teddington TW10 0LW.
2. Linear Instruments Ltd, 9 Raynham Road, Bishop's Stortford CM23 5PB.
3. Beta Instrument Company Ltd, Halifax House, Halifax Road, Cressex Industrial Estate, High Wycombe NP12 3SW.
4. Coteglade Photonics Ltd, Brunel House, 1275 Neath Road, Hafod, Swansea SA1 2LB.
5. Ealing Electro-Optics Ltd, Greycaine Road, Watford WD2 4PW.
6. Ultrafine Technology Ltd, 16 Foster Road, Chiswick, London W4 4NY.

# EVENTS

## Science 88

The 150th Annual Meeting of the British Association for the Advancement of Science will take place this year in Oxford from 5 to 9 September. The Meeting will be hosted by the University of Oxford, the Oxford Polytechnic, the City of Oxford, and Oxfordshire County Council. Most scientific events will take place in the Science Area of the University. The Science Departments of both the University and the Polytechnic will be offering a range of activities, exhibitions, and receptions. There will be a special opening of the historic Botanic Gardens for delegates, and exclusive tours to the Bodleian Library, the Ashmolean Museum, and Christ Church Picture Gallery.

Other exhibitions will include 'Science in Business and Industry', organized by Mack-Brooks; 'Forensic Science' from the Home Office; 'The Growth of the Small Country Hospital' from the Oxfordshire Health Authority; 'Oxford Science and Industry'; and an exciting scientific 'Amusement Arcade', in which young and old can try out for themselves all the latest interactive technology and 'hands-on' experiments.

Full details from **British Association for the Advancement of Science • 23 Saville Row • LONDON W1X 1AB.**

## IEE meetings this month

1 Expert systems for NDT
13-17 Eurocon 88 (Stockholm)
15 Permanent-magnet machines
16 AGM
21-23 Private switching systems and networks

Details from **The Institution of Electrical Engineers • Savoy Place • LONDON WC2R 0BL • Telephone 01-240 1871** except for Eurocon 88 for which details may be obtained from **Eurocon 88 c/o Stockholm Convention Bureau • PO Box 1617 • S-111 86 STOCKHOLM • Sweden.**

## European UNIX User Show

Exhibition of hardware, software, peripheral systems, and services related to the UNIX Operating System to be held at the Alexandra Palace Pavilion, LONDON N22. Details from **EMAP International Exhibitions Ltd • Abbot's Court • 34 Farringdon Lane • LONDON EC1R 3AU • Telephone 01-608 1161.**

The **SEMI European ISS Industry Forecast Conference** will be held at Hotel Penta, Munich, Federal Germany. Full details from **SEMI European Secretariat • CCL House • 59 Fleet Street • LONDON EC4Y 1JU • Telephone 01-353 8807.**

The **Dataquest Seventh Annual European Semiconductor Conference** will be held from 8 to 10 June at the Gleneagles Hotel, Auchterarder, Scotland. Full details from **Cochrane Communications Ltd • CCL House • 59 Fleet Street • LONDON EC4Y 1JU • Telephone 01-353 8807.**

**Online International** is organizing three shows at the Wembley Exhibition and Conference Centre, London, this month. The first is the 'Second Software Tools Exhibition' from 14 to 16 June. The second, 'European Computer and Communications Conference and Exhibition', and the third, the 'Seventh Networks Exhibition', will be held concurrently from 21 to 23 June.

Full details from **Online International Ltd • Pinner Green House • Ash Hill Drive • PINNER HA5 2AE • Telephone 01-868 4466.**

# TEST & MEASURING EQUIPMENT

## Part 3: Function Generators

by Julian Nolan

### Thandar TG102

Thandar produce a wide range of British designed products, extending from a miniature oscilloscope, the SC110A, to their main line: signal generators and frequency counters.

The TG102 is of the compact 2 MHz variety. As far as price is concerned (£160 excl VAT), it fits in between the TG101 and TG501, which have frequency ranges of 200 kHz and 5 MHz respectively.

Weighing 1.2 kg and measuring 255×150×50 mm (W×L×H), the TG102 may be called a portable instrument. It is supplied with a good length of standard IEC terminated mains lead, and can be operated from either 110 VAC or 240 VAC. Altering of the operating voltage cannot be done externally, but requires resoldering of some taps on the mains transformer.

The TG102 is provided with a swivel stand and, although this has only one stop position, it can be rotated through 360°, which facilitates stacking of the instrument.

The appearance of the TG102 is, perhaps, a little unconventional, with the function selectors and on/off switch mounted at the left, the frequency and selection controls in the centre, and the output amplitude and off-set controls fitted at the right of the front panel.

The very small size of the TG102 makes it eminently suitable for applications that require the instrument to be used in a small or restricted space. It is a pity, however, that a battery option is not available: that would make the instrument **really** portable.

The output frequency is read on a logarithmic scale which is calibrated from 0.2 Hz to 2 MHz. Each of the six ranges is selected by a rotary switch, which acts as a multiplier to the figure set on the vernier control. The frequency range actually available extends from 0.15 Hz to 2.036 MHz without the use of the external VCF facility. On the review instrument some instability occurred at frequencies ≦0.3 Hz. This was also noticeable at the extreme end of the scale on the other ranges, but this does not really matter since all ranges overlap.

It is a pity that a duty cycle, or symmetry, control is not fitted, because this limits the versatility of the instrument as regards the number of waveforms that can be generated over and above the standard three. The mark:space accuracy is very good, however, and is well within the quoted 1% up to 100 kHz, and not much above this at 2 MHz.

Frequency stability is good with the minimum of variation with time over all six ranges, with the exception of the slight instability problem mentioned earlier. Square-wave rise-time on the main output is of the order of 50 ns, while the rise-time on the TTL output is about 10 ns.

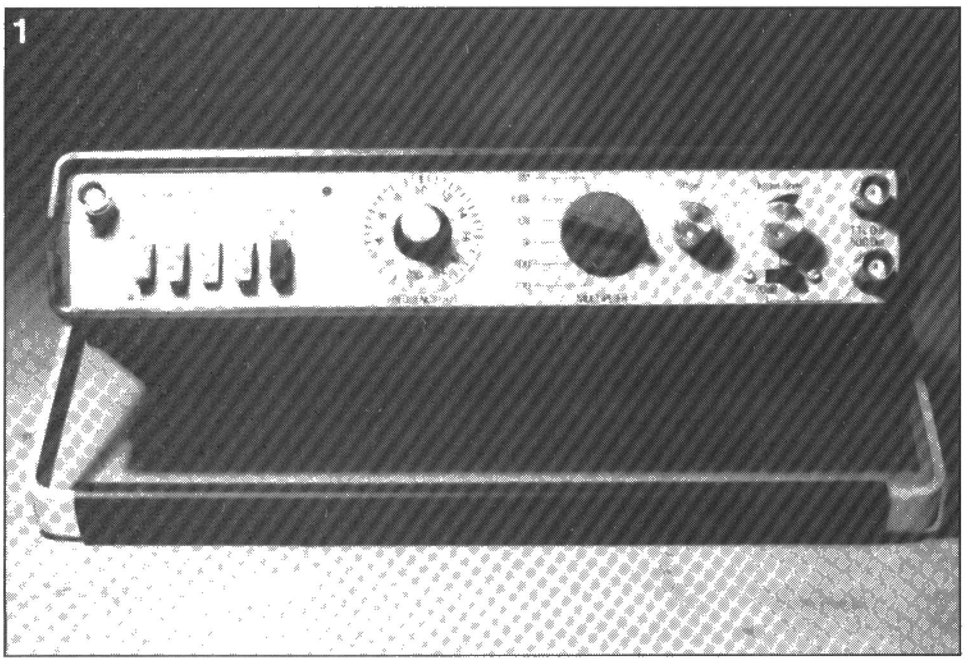



Fig. 1. General view of the Thandar TG102.

Output waveforms available are sine, square, and triangular. With all the range selectors off, there is also a constant d.c. output, which is useful for threshold testing of a circuit and eliminates the need for an external d.c. source. The d.c. output level is adjustable by the off-set control from −10 V to +10 V into a 1 MΩ load.

Distortion is low on most ranges: typically below 1% up to 150 kHz and well below the quoted 4% at 2 MHz. However, in the sine-wave mode on frequencies ≧1 MHz, the review instrument exhibited some distortion in the form of a slightly extended trough.

The output amplitude was practically constant over the whole frequency spectrum, except for a variation of 0.7 dB in the sine-wave mode at frequencies from 100 kHz to over 2 MHz. The output level is 20 $V_{pp}$ into 1 MΩ (or 10 $V_{pp}$ into 50 Ω), which can be reduced to 560 mV without the 20 dB attenuator switched in, and 60 mV with the attenuator in circuit. No increase in distortion is noticeable at these lower levels. For some applications, a lower output of, say, 10 mV might have proved useful.

A sensitive VCF input facility is provided: an input of −5 V causes a frequency sweep of about 2000:1. The start frequency is dependent on the setting of the frequency control, which also affects the maximum sweep range. The frequency can also be swept upwards by a positive input of similar amplitude: the maximum frequency of the instrument (highest range) is then increased to about 2.755 MHz.

The 14-page manual, of which six pages are in English, is fairly limited, although reasonably detailed sections are included on modes of operation and external sweep operation. There is, however, no circuit diagram or service information, although a service manual is available separately.

External construction is based on a two-piece plastic enclosure with aluminium insets for the front and rear panels. This gives a very good finish and makes the instrument appear reasonably rugged. The swivel stand is aluminium and, in contrast to some other instruments, matches the rest of the enclosure as far as ruggedness is concerned.

**Table 1**

OPERATING RANGE

Frequency range: <0.2 Hz to 2 MHz in 6 calibrated ranges: fine adjustment by vernier, calibrated from 0.2× to 2× main setting.
Frequency accuracy: ±5% of full scale on 1 kHz to 1 MHz; better than ±8% on 10 Hz and 100 Hz ranges.
External sweep range: variable over >1000:1 ratio (>100:1 lowest range) by 5 $V_{pp}$.
Input impedance: 10 kΩ
Maximum slew rate: 0.1 V/μs.

OPERATING MODES

Sine wave: distortion <0.5% on 100 Hz, 1 kHz, and 10 kHz ranges; <1% on 10 Hz and 100 kHz ranges; harmonics >25 dB below fundamental on 1 MHz range; amplitude flatness <±0.2 dB up to 200 kHz, <±1 dB from 200 kHz to 2 MHz.
Square wave: mark:space ratio 1:1 ±1% to 100 kHz.
DC range: ±5 V into 50Ω.
DC off-set: variable ±5 V into 50Ω.

OUTPUTS

50Ω: <0.6 V to 20 $V_{pp}$ from 50Ω ±1% source; <0.3V to 10 V across 50 Ω load; switched attenuator reduces signal and d.c. off-set by 20 dB; output protected against short-circuits.
TTL: capable of driving up to 20 standard TTL loads.

GENERAL
Mains voltage: 110-120-220-240 VAC 50/60 Hz internally adjustable.
Power consumption: 12 VA.
Dimensions: 255×150×50 mm (W×D×H).
Weight: 1.2 kg.
Accessories supplied: mains lead (IEC terminated); manual.
Warranty: 1 year.

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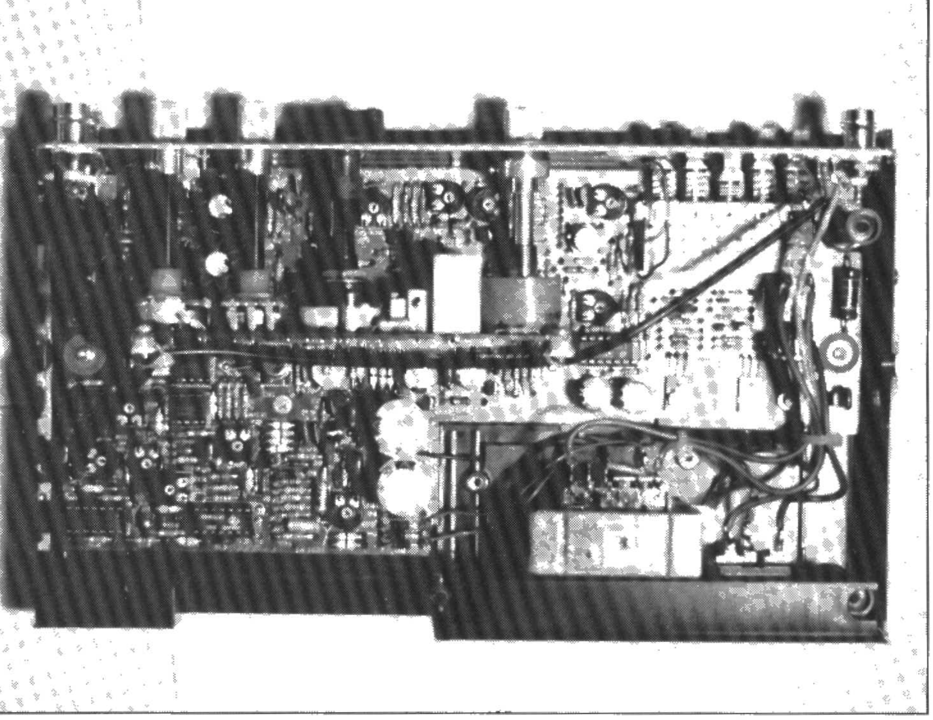

**Fig. 2. Inside view of the Thandar TG102.**

Table 2

| | Unsatis-factory | Satis-factory | Good | Very good | Excellent |
|---|---|---|---|---|---|
| Dial accuracy | | | | x | |
| Dial resolution | | | | x | |
| External sweep range | | | | x | |
| Distortion | | | | x | |
| Frequency range | | | x | | |
| Output level range | | | | | x |
| Internal construction | | | | | x |
| External construction | | | | x | |
| Overall specification | | | x | | |
| Ease of use | | | | x | |
| Manual | | x | | | |

Internal construction is to the same high standard. It is based on two PCBs, one horizontally mounted and housing the generator circuitry, and the other, smaller board, mounted vertically and containing some of the user control circuits. Both boards are silk-screened with component numbers and, where appropriate, their functions, which is obviously very useful when servicing is required. All ICs are fitted in sockets.
Heat dissipation is fairly low, which is surprising since the main PCB has a fairly high component density. The mains transformer is chassis mounted, as are some of the regulating transistors. Connecting wires have been kept to a minimum through the use of a separate PCB for most of the user controls. Mains connections are not insulated inside the instrument, so extra care has to be taken during the servicing of the generator.

## Conclusion

The TG102 is ideal for applications which demand small size and a reasonable specification. It does lack one or two of the facilities offered by some of its rivals, such as symmetry control, and this should, of course, be taken into consideration.
The performance of the TG102 is good, with particularly low distortion throughout the frequency range and across most of the output amplitudes.
Perhaps **the** outstanding point of the TG102 is its very high standard of finish and construction, particularly in its price range, and this should appeal to a great number of professional users.

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The TG102 was supplied by Thandar Electronics Limited, London Road, St Ives, Huntingdon, Cambridgeshire PE17 4HJ, telephone (0840 64646).

## Thandar TG101

The TG101 is similar to the TG102 in many respects, and the following review will, therefore, only deal with the differences between the two instruments.

The main difference is the max. output frequency, which in the TG101 is 200 kHz.

Distortion is good on all ranges, typically about 0.6%, except on the 100 k multiplier range where it rises to 1.3% and increases slightly further when the output frequency approaches 200 kHz.

Square-wave rise-time from the main 600-ohm output is typically 85 ns, and that from the TTL output 9 ns.

The vernier control is effective over the whole range (0.011 Hz to 21 Hz on the lowest range) with good accuracy. The maximum output frequency that can be set by the vernier is 202.51 kHz: with the sweep facility used, this rises to 314.12 kHz.

The output amplitude is very stable: typically within 2.5% over the entire range. The amplitude is 10 $V_{pp}$ max into 1 MΩ and can be reduced to about 4 $mV_{pp}$ with the aid of the built-in 40 dB attenuator. Little or no increase in distortion is noticeable at the reduced levels.

The sweep-in facility is particularly good, and covers from 0.3 Hz to 314 kHz in one sweep on the maximum multiplier tange, although it is, perhaps, not surprising that at this sweep ratio some distortion occurs at frequencies below about 5 Hz. The sweep voltage required is 0-8.5 V. A similar sweeping range can be obtained with negative voltages of the same magnitude if the vernier and multiplier controls are set correctly. However, sweeping becomes increasingly non-linear outside the specified limits of 1000:1.

The manual, like that of the TG102, contains only the minimum of information and does not include a circuit diagram. It does, however, contain a fairly detailed description of the instrument and its modes of operation. A service manual is available separately.

## Conclusion

The lack of a variable symmetry control is not so important here as in the TG102, assuming that the TG101 is to be used primarily as an audio testing instrument. Construction, both internal and external, is to the same high standards as that of the TG102.

The TG101 should perform well as an audio testing instrument, or low-frequency function generator, in most environments and especially where a good low-level performance is required.

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The TG101 was supplied by Thandar Electronics Ltd, London Road, St Ives, Huntingdon, Cambridgeshire PE17 4HJ, telephone (0480) 64646.

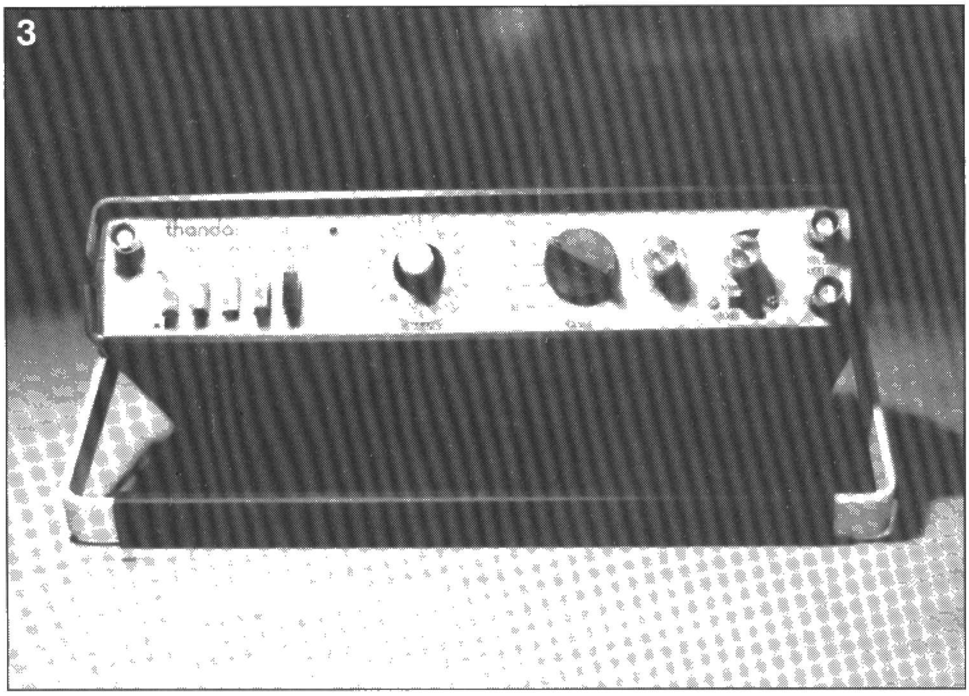

Fig. 3. General view of the Thandar TG101.

**Table 3**

OPERATING RANGE

Frequency range: <0.2 Hz to 200 kHz in 5 calibrated ranges; fine adjustment by vernier, calibrated from 0.2× to 2× main setting.
Frequency accuracy: ±5% of full scale on 100 Hz to 100 kHz; better than ±8% on 10 Hz range.
External sweep range: variable over >1000:1 ratio (>100:1 lowest range) by 5 $V_{pp}$.
Input impedance: 10 kΩ.
Maximum input: ±10 $V_{pp}$.
Maximum slew rate: 0.1 V/μs.

OPERATING MODES

Sine wave: distortion <1% on 100 Hz, 1 kH, and 10 kHz ranges; <2% on 100 kHz range; amplitude flatness <±0.2 dB up to 200 kHz.
Square wave: mark:space ratio 1:1 ±1% to 100 kHz.
DC range: ±5 V into 50Ω.
DC off-set: variable ±5 V into 50Ω.

OUTPUTS

50Ω: <0.6 V to 20 $V_{pp}$ from 50Ω ±1% source; <0.3V to 10 V across 50Ω load; switched attenuator reduces signal and d.c. off-set by 40 dB; output protected against short-circuits.
TTL: capable of driving up to 20 standard TTL loads.

GENERAL

Mains voltage: 110-120-220-240 VAC 50/60 Hz internally adjustable.
Power consumption: 12 VA.
Dimensions: 255×150×50 mm (W×D×H).
Weight: 1.2 kg.
Accessories supplied: mains lead (IEC terminated); manual.
Warranty: 1 year.

Table 4

| | Unsatis-factory | Satis-factory | Good | Very good | Excellent |
|---|---|---|---|---|---|
| Dial accuracy | | | | x | |
| Dial resolution | | | | x | |
| External sweep range | | | | | x |
| Distortion | | | | x | |
| Frequency range | | | x | | |
| Output level range | | | | | x |
| Internal construction | | | | | x |
| External construction | | | | x | |
| Overall specification | | | | x | |
| Ease of use | | | | x | |
| Manual | | x | | | |

## Other signal sources available in the Thandar range

**TG501** — 0.005 Hz to 5 MHz frequency range; <0.5% distortion to 50 kHz (<1% to 500 kHz); continuous, triggered, or gated modes; variable start/stop phase; 3 output attenuators; 19:1 symmetry range; price £325 excl VAT.

**TG502** — as TG501 plus sweep function generator: 1000:1 linear or 10,000:1 log sweep with variable marker duration; variable sweep rate; single sweep; sweep reset and hold functions; sweep and pen lift outputs; price £545 excl VAT.

**TG503** — as TG501 plus pulse/function generator; normal, double, or delayed pulse modes; 10 MHz double-pulse mode; variable width and delay; price £545 excl VAT.

**TG401** — 4 MHz programmable function generator; 0.004 Hz to 4 MHz frequency range; continuous, sweep, triggered, or gated modes; GPIB compatible; 4-digit resolution; storage of 99 complete settings; <1% distortion from 10 Hz to 100 kHz; price £1, 290 excl VAT or, with synthesizer option, £1,605 excl VAT.

**TG105** — Pulse generator; 5 Hz to 5 MHz PRF; 10 ns rise-time; continuous, gated, or triggered modes; price £105 excl VAT.

## Leader LSG-17

Leader, a Japanese company, manufactures a wide range of test equipment and has a reputation for providing well-constructed instruments at a competitive price/performance ratio. The LSG-17 is no exception and is one of only a small number of RF generators in the price range of up to £150.

The appearance of the instrument is, perhaps, somewhat unconventional when compared with its rivals, although the nearly-square front panel allows relatively accurate scaling and consequent setting of the required frequency.

The mains lead is of a reasonable length which, since it is fixed, is just as well. Mains voltage selection is internal: 100, 120 or 240 VAC is catered for.

The output terminals are located at the right of the instrument. To the left of these is a pair of sockets for connecting a crystal. At the centre of the front panel are input/output terminals that serve as output of the internal modulation or as input for external modulation.

Owing to the shape of the enclosure it is not possible to incorporate a stand into the design, but, to improve the portability, a carrying handle is provided.

Dimensions are modest: 238×130×150 mm (W×D×H), but the shape may make stacking of the instrument difficult.

A reduction drive with a ratio of about 5:1 is used to select the output frequency in one of 6 ranges by a rotary control. The frequency range extends from 100 kHz to 150 MHz on fundamentals, or up to 450 MHz if 3rd harmonics are used. Scale accuracy is very good and within the quoted ±1.5% over all ranges, including minimum and maximum frequencies.

The actual frequency range covers 99.29 kHz to 155 MHz. The frequency can be set by either the calibrated control or, more stably and accurately, an external crystal, whose frequency must lie in the 1 MHz to 15 MHz range. In the external crystal mode, the output is, unfortunately, set at constant amplitude (typically 600 $mV_{pp}$ for a 6 MHz crystal), which restricts the instrument's use in applications that require a very-low level output, unless an external attenuator is used. Frequency stability in this mode is obviously the main advantage: it matches that of the crystal (Type FT-243 recommended) and enables the LSG-17 to be used for such purposes as frequency calibrator (for non-critical situations), marker frequency, or reference. In addition, the crystal frequency can be superimposed on the generator frequency: the depth of modulation, as well as the output amplitude, can be controlled with the fine output amplitude control.

Other output modes include internal or external modulation. Internal modulation is set at 1 kHz and at a depth of 30%, although the symmetry of the modulating sine wave can certainly not be said to be in a 1:1 ratio; it is nearer to 4:5. However, internal modulation makes the LSG-17 considerably more versatile, and the slight modulation distortion will probably not affect the vast majority of users.

In addition, the 1 kHz modulation signal is also available at the output/input sockets. But even there, perhaps not surprisingly, it exhibits a slight symmetry error; this is perfectly acceptable for such purposes as synchronization, however.

External modulation may be used between 50 Hz and 20 kHz: an input amplitude of 150 mV gives a depth of modulation of 30%. Maximum depth is about 60%; when this is increased, excessive distortion of the AM signal occurs. However, the sensitive input allows a wide range of external modulating signals to be connected to the instrument without the necessity of any pre-amplification.

The output amplitude in the internal and external modulation modes ranges typically from 4 $mV_{pp}$ to 600 $mV_{pp}$ into 1 MΩ. As can be expected from a generator of this type, the output level flatness varies considerably on approaching the maximum output frequency, although even then a good output amplitude is maintained. The output amplitude itself is selected from one of two coarse ranges of 4–40 $mV_{pp}$ and 15–800 $mV_{pp}$ (measured at 20 MHz into 50Ω) with a relatively high resolution. In the internal modulation mode, a peak-to-peak constant output amplitude of 8 V into 1 MΩ is available from the input/output

4

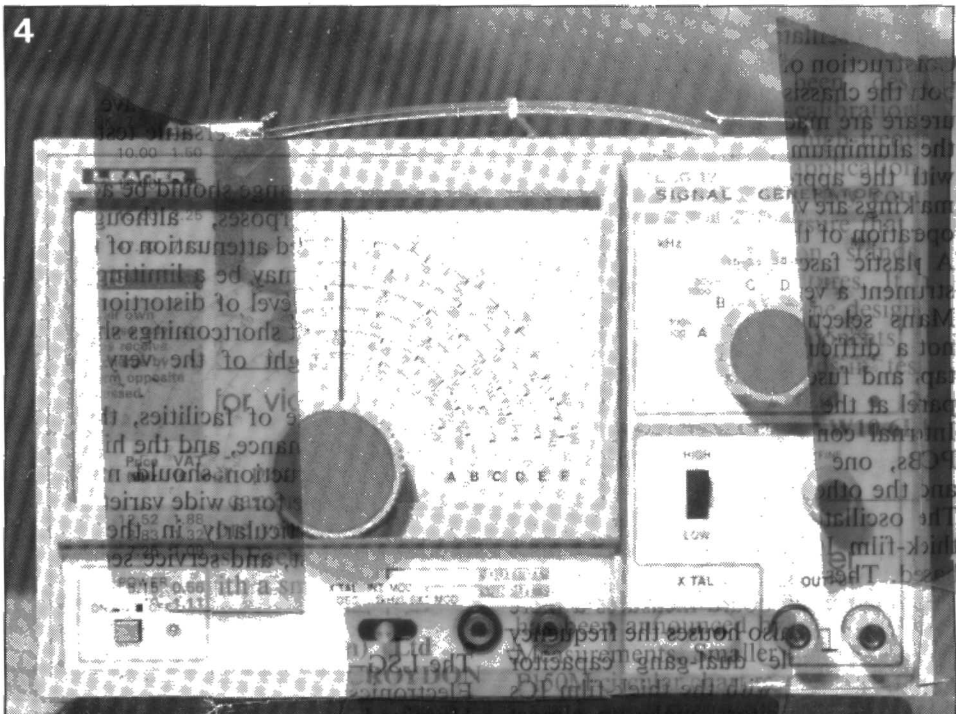


Fig. 4. General view of the Leader LSG-17

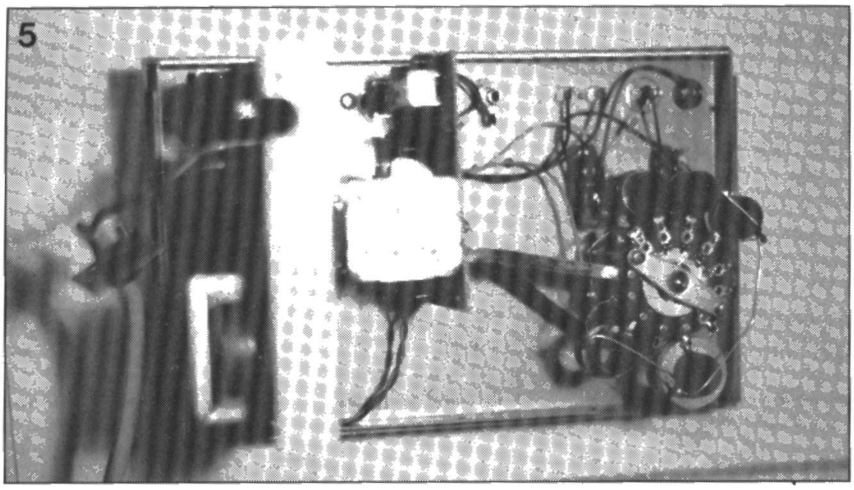

Fig. 5. Inside view of the Leader LSG—17.

Table 6

| | Unsatis-factory | Satis-factory | Good | Very good | Excellent |
|---|---|---|---|---|---|
| Dial accuracy | | | | | x |
| Dial resolution | | | | x | |
| External sweep range | | | | NA | |
| Distortion | | x | | | |
| Frequency range | | | | x | |
| Output level range | | | | x | |
| Internal construction | | | | | x |
| Overall specification | | | | x | |
| Ease of use | | | | x | |
| Manual | | | | x | |

Table 5

OPERATING RANGE

Frequency range: 100 kHz to 150 MHz (fundamentals) or 100 kHz to 450 MHz (3rd harmonics); fine adjustment by calibrated control; accuracy ±1.5% of full scale.

OPERATING MODES
Amplitude modulation: internal 30% depth at 1 kHz; external 50 Hz to 20 kHz — 150 mV input gives 30% depth of modulation.

OUTPUTS
RF output: 100 mV r.m.s. up to 35 MHz (open circuit), controlled by high/low switch and variable control.

GENERAL
Mains voltage: 100, 115-120, 220-240 VAC; 50/60 Hz; internally adjustable.
Power consumption: 3 VA.
Dimensions: 238×130×150 mm (W×D×H).
Weight: 2.5 kg.
Accessories supplied: manual.
Warranty: 1 year.

sockets.
As may be expected, distortion is fairly high over all ranges. It does not appear to be dependent on the output amplitude and should not present a major problem, particularly if the market the LSG-17 is aimed at is taken into consideration.
Distortion is also present in the crystal oscillator mode,but at a slightly reduced level compared to that produced by the internal oscillator.
Construction of the LSG-17 is first class: both the chassis and the two-part enclosure are are made from sheet steel, while the aluminium front panel is screened with the appropriate markings. These markings are very clear and should make operation of the generator an easy task.
A plastic fascia surround gives the instrument a very neat and robust finish.
Mains selection, although internal, is not a difficult matter as the selection taps and fuse are accessible via a small panel at the rear of the enclosure.
Internal construction is based on two PCBs, one housing the power supply and the other the oscillator circuitry.
The oscillator board contains the two thick-film ICs on which the design is based. These ICs make for a very compact design: the board measures a mere 90×70 mm. It also houses the frequency control variable dual-gang capacitor which, together with the thick-film ICs and a few capacitors, make up almost the entire component count. The necessary inductors are mounted direct on the range selector to minimize any losses.
Servicing the instrument should be very easy as far as fault location is concerned, although the removal and replacement of either of the thick-film ICs may present a small problem.

## Conclusion

Functions such as AM, external Xtal oscillator, and a 1 kHz sine-wave output make the LSG-17 a versatile test instrument.
The frequency range should be adequate for most purposes, although the frequency-related attenuation of the output amplitude may be a limiting factor, as may be the level of distortion. However, these slight shortcomings should be seen in the light of the very advantageous price.
The wide range of facilities, the good level of performance, and the high standard of construction should make the LSG-17 suitable for a wide variety of applications, particularly in the educational, hobbyist, and service sectors.

The LSG—17 was supplied by Thandar Electronics Ltd. London Road, St Ives, Huntingdon, Cambridgeshire PE17 4HJ, telephone (0480) 64646.

## Other signal sources available in the Leader range

**LAG-27** — audio generator; 10 Hz to 1 MHz; reduction drive; sine and square-wave outputs; price £161 excl VAT.

**LAG-120A** — audio generator; 10 Hz to 1 MHz; flat output response (±0.5 dB); synchronization with external source possible; 0.05% distortion (500 Hz to 20 kHz); price £245 excl VAT.

**LAG-125** — low-distortion audio generator; 10 Hz to 1 MHz; burst facility; distortion 0.03% (500 Hz to 20 kHz); price £385 excl VAT.

**LFG-1300** — sweep/function generator; 0.002 Hz to 2 MHz; distortion 0.5% (10 Hz to 20 kHz); linear and log sweep; AM; symmetry variable to 40:1; variable sweep rate; price £660 excl VAT.

**LSG-216** — 115 MHz synthesized signal generator; battery-backed 100 point memory; 6-digit frequency display; stereo modulation; 0.1 MHz to 30 MHz and 75 MHz to 115 MHz ranges price £2041 excl VAT.

**LSG-215A** — 120 MHz synthesized signal generator same as LSG—216 but with continuous range from 100 kHz to 120 MHz; price £2103 excl VAT.

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| automate your model railway 1 × 2716 | 537 | 7.30 | 1.10 |
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| MIDI signal distribution | 87012 | 7.40 | 1.11 |
| Spot sine wave generator | 87036-1 | not available | |


| | No. | Price (£) | VAT (£) |
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| **MAY 1987** | | | |
| Capacitance meter | 86042 | 5.15 | 0.56 |
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| Spot sine wave generator | 87036-1 | not available | |


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| meter | 880005 | 9.25 | 1.39 |

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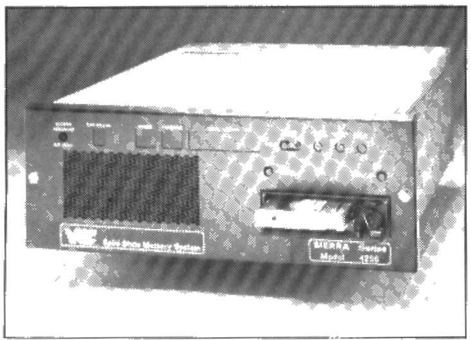
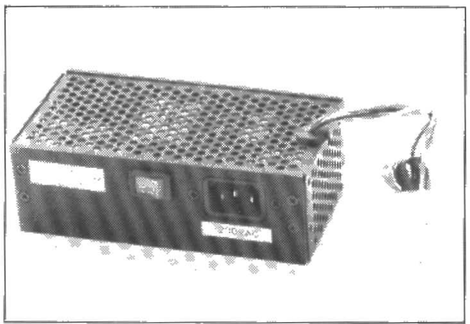


## Solid-state memory system

A new range of ultra-compact, solid-state memory systems with very fast access time has been announced by Vermont Research.

To be marketed under the name 'Sierra', the new range combines full emulation of traditional disc storage devices with the speed and reliability of high-speed semiconductor memories to give users a flexible and fast solution to problems with data access bottlenecks.

**Vermont Research • Cleeve Road • LEATHERHEAD KT22 7NB • Telephone (0372) 376221.**



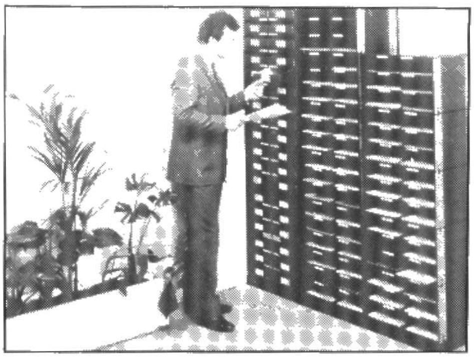
## Compact 50 W switching supplies

Designed to exceed the safety standard of UL478 and CSA C22.2#154, and with built-in EMI filtering, the PX53 series of power supplies from Powerail fits into an enclosure little larger than a cigarette packet. With 50 W output, excellent noise performance, 1.5 kV input-output isolation, and overvoltage and overcurrent protection, the PX53 is well suited to applications in CRT modems and microprocessor-based products.

**Powerail Electronics Ltd • 6B Princes Street • DUNSTABLE LU6 3AX • Telephone (0582) 600277.**

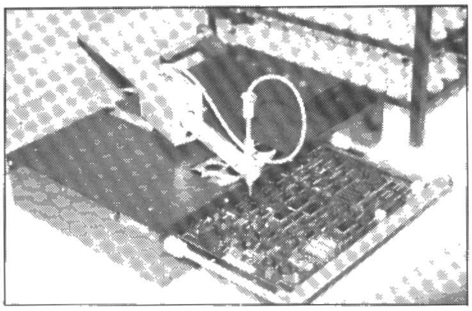
## Keeping sales literature under control

Retailers handling quantities of leaflets and brochures on all kinds of electronic products need swift access to them. Also, this literature needs to be kept in pristine condition. The Stax-Sorter literature organizer from Fellowes



enables both these requirements to be met.

**Fellowes Manufacturing (UK) Ltd • Doncaster Road • Kirk Sandall • DONCASTER DN3 1HT • Telephone 01-836 2205.**

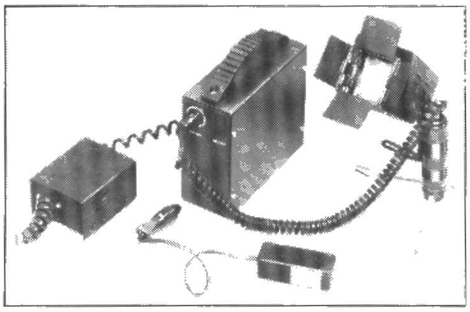


## PCB pick-and-place machine

The Sumo-polar pick-and-place machine from Toolrange comprises a 50-slot rotating component carousel, a manually operated sliding suction head that rotates through 360°, and an adjustable spring-loaded PCB holder.

The machine is ideal, in pilot or small batch production, for the accurate picking and placing of PCBs of large numbers of small components.

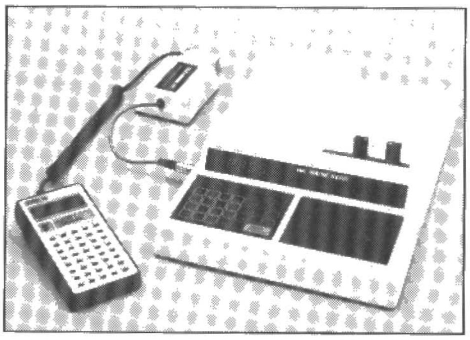
**Toolrange Ltd • Upton Road • READING RG3 4JA • Telephone (0734) 29446.**



## Power pack for video cameras

The Polar power pack, specially designed for video cameras, offers a less expensive and more versatile alternative to existing systems. Each pack comprises a 6 Ah battery with a small charger and adapter lead.

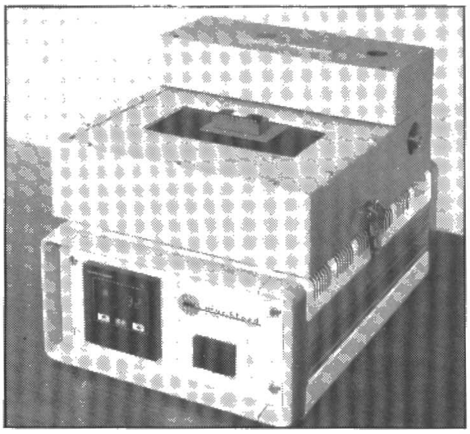
**Jackson Brothers (London) Ltd • Kingsway • Waddon • CROYDON CR9 4DG • Telephone 01-681 2754/7.**



## Low-cost LCR meter

The Type 4250 LCR meter from Wayne Kerr is a low-cost addition to the company's range of instruments. It can test the resistance, capacitance, inductance, and other characteristics of passive components at the rate of 10,000 per hour. The unit can store up to 15 complete test sequences. Once such programs have been entered, they can not be altered by the operator, ensuring that test schedules are always consistent and complete.

**Wayne Kerr Instruments Ltd • Durban Road • BOGNOR REGIS PO22 9RL • Telephone (0243) 825811.**



## Temperature calibration on a plate

The TempPlate has been designed specifically for the calibration of microwave and other high-frequency devices. Its main application is calibrating assemblies as they come of the production line to ensure that their performance specification stands up over a range of temperatures. It may, however, also be used in the design and evaluation testing of components' thermal characteristics or 'goods in' testing.

**Montford Instruments Ltd • 24-26 Gorst Road • LONDON NW10 6LE • Telephone 01-965 0361.**

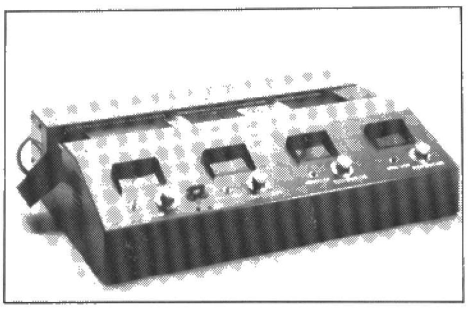
## Circular chart recorder

A new circular chart recorder, the P70M, has been announced by Kent Industrial Measurements. Smaller than the proven P150M circular chart recorder, the P70M provides versatile control of input ranging and linearization with control of the

# NEW PRODUCTS

pen drive and referencing, visual alarms and control outputs, and all at a lower cost.

**Kent Industrial Measurements Ltd • Howard Road • Eaton Scoton • St Neots • HUNTINGDON PE19 3EU • Telephone (0480) 75321.**

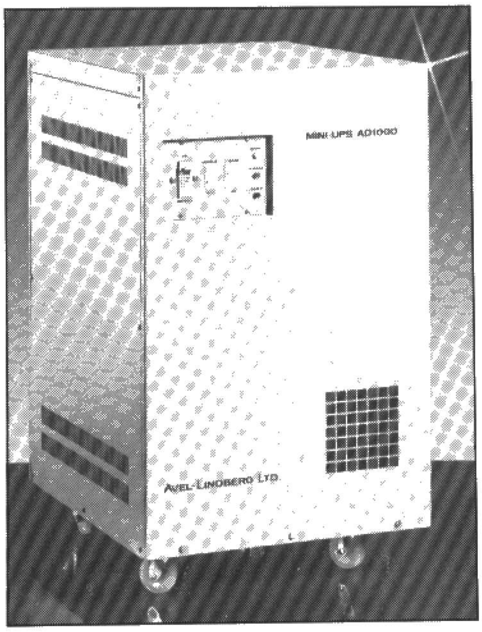


## Low-cost reflow soldering system

The Falcon 3 conductive reflow soldering system is intended for surface-mount and hybrid thick-film applications.

Manufactured by Sikama, the Falcon 3 is a table top unit that provides three heat zones and is ideal for circuits measuring up to 70×114 mm.

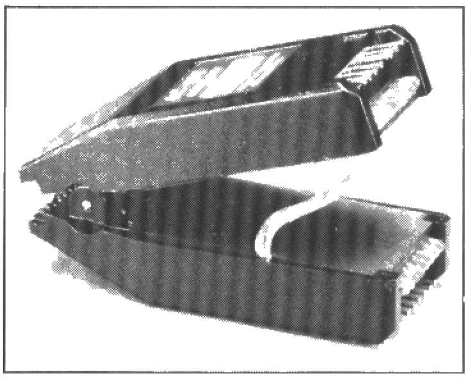
**Jidenco Machines International Ltd • Jidenco House • Vale Road • WINDSOR SL4 5JW • Telephone (0753) 860343.**



## Versatile mini UPS

The Avel-Lindberg AD1000 uninterruptible power supply has been designed to fulfill a number of roles, including plug-to-plug compatibility between any computer, or other electronic system, with a load requirement of up to 1 kVA, for periods of up to 40 minutes from an internal battery for operation through commercial power failure, and for up to three hours from an external battery.

**Avel-Lindberg Ltd • SOUTH OCKENDON RM15 5TD • Telephone (0708) 853444.**



## ESD-safe logic clip

A new logic clip, the Type LC-160 from OK, has a conductive housing to make it ESD safe. It will monitor up to 16 pins and can also function as an IC test clip, making it a convenient fault-finding tool.

**OK Industries Ltd • Barton Farm Industrial Estate • Chickenhall Lane • EASTLEIGH SO5 5RR • Telephone (0703) 619841.**

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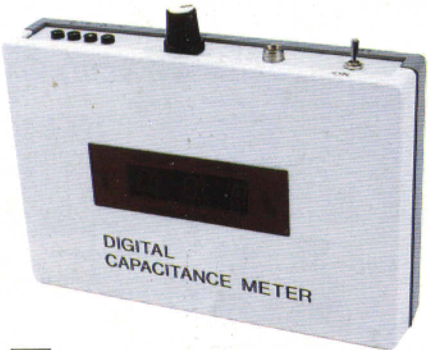


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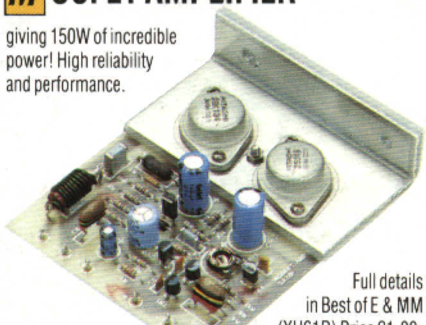

Full details in Best of E & MM (XH61R) Price £1.00.

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All prices include VAT. Please add 50p towards postage.

## MUSICAL DOORBELL

with 28 tunes and chimes with selectable piano to organ like sounds. Note: case and front panel not in kit. For full details see Project Book 13 (XA13P) Price 85p.


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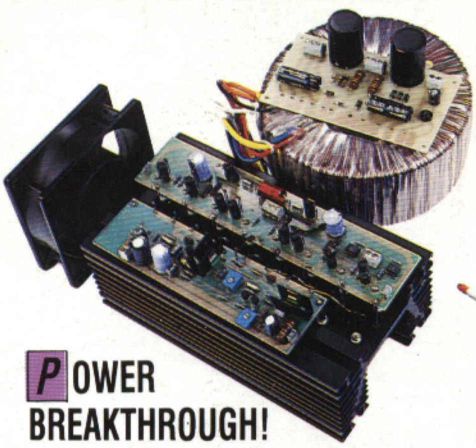

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A superb 1kW Mosfet amplifier, a major new source in sound! Full details in Project Book 26 (XA26D) Price 85p. This project is made up from 4 kits.

KIT PRICE

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|---|---|---|---|
| LM50E | LM51F | LM52G | LM53H |
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capable of measuring the level of Alpha and Beta particles, and Gamma and X-Rays. Full details in Project Book 24 (XA24B) Price 85p.

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All items subject to availability

Maplin Electronics
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